

Detection and Evaluation of Elevated Lead Release from Service Lines: A Field Study

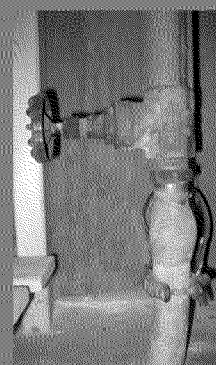
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* Supporting Information

Comparative stagnation sampling conducted in 32 homes in Chicago, Illinois with lead service lines demonstrated that the existing regulatory sampling protocol under the U.S. Lead and Copper Rule systematically misses the high lead levels and potential human exposure. Lead levels measured with sequential sampling were highest within the lead service lines, with maximum values more than four times higher than Chicago's regulatory compliance results using a first-draw sampling protocol. There was significant variability in lead values from different points within individual lead service lines and among different lead service line sites across the city. Although other factors could also influence lead levels, the highest lead results most often were associated with sites having known disturbances to the lead service lines. This study underscores the importance and interdependence of sample site selection, sampling protocol, and other factors in assessing lead levels in a public water system.



INTRODUCTION

Background. Most lead in drinking water comes from premise plumbing materials and lead service lines (LSLs). LSLs are generally the largest source of lead in drinking water when they are present in public water systems.¹ The 1986 Safe Drinking Water Act Amendments banned new lead pipes in the potable water network, but a legacy of millions of partial or whole LSLs remains in many public water systems.² Where the term "lead corrosion" is used, it refers to the corrosion of lead plumbing materials that result in the transfer of dissolved or particulate lead into the drinking water.

The Lead and Copper Rule (LCR) sampling is intended to measure the lead levels in drinking water to assess the effectiveness of corrosion control treatment utilized by public water systems (PWSs) to minimize lead in drinking water. PWSs are required to use sampling sites that are presumed to be the highest-risk sites for lead release, and to optimize corrosion control to minimize lead levels at consumers' taps. Most published sampling studies typically focus on systems having high lead levels or systems that have experienced challenges in attempting to balance LCR compliance with various other treatment or water quality objectives. Except for LCR compliance data, little published data exists or is available for systems that are considered to be operating with optimal corrosion control and meeting the lead action level (AL) in the LCR. This study focuses on a system that is considered to have optimized corrosion control using a blended phosphate, with a relatively stable water quality, and compliance results historically well below the lead AL. This situation is representative of a large percentage of systems serving 100,000 or more people that utilize orthophosphate or blended phosphates for corrosion control and the vast majority of

systems are meeting the lead AL based on the current sampling protocol in the LCR. Additional information on the LCR and study is available in the Supporting Information (SI). This study focused on whether (1) the current LCR compliance sampling protocol adequately captures the peak lead levels in a water system; (2) "preflushing" (PF) results in capturing lower lead levels in samples compared to samples collected under normal household usage (NHU) conditions; (3) a first-draw sampling protocol appropriately determines the adequacy of optimal lead corrosion control in water systems with LSLs; and (4) there is seasonal variability in the sampling results using the different sampling protocols.

System Information. The Chicago Department of Water Management (CDWM) operates two similar conventional surface water filtration treatment plants serving approximately 5.4 million residents, including those in 125 suburbs. Lake Michigan is the sole water source, with relatively stable water quality leaving the treatment plants and in the distribution system (Table 1). Before the LCR, CDWM utilized pH/alkalinity adjustment for corrosion control. CDWM switched to a proprietary blended phosphate at both plants between 1993 and 1994 which is still used as the primary corrosion control treatment.

The LCR requires public water systems to collect lead samples using a first-draw (FD) sampling protocol, and samples were collected almost exclusively from single-family homes with LSLs as required by the LCR sample site selection require-

Received: January 23, 2013

Revised: June 24, 2013

Accepted: July 23, 2013

Table 1. Water Quality Data 2011

parameter	outlets		distribution	
	min	max	min	max
temp (°C)	4	24	5	23
turbidity (NTU)	0.1	0.2	0.1	0.4
pH	7.5	7.8	7.7	7.8
Cl ₂ residual (mg/L)	1.0	1.2	0.7	0.9
total alkalinity (mg/L as CaCO ₃)	103	108	98	108
chloride (Cl, mg/L)	16	20	17	20
sulfate (mg/L)	29	31	29	30
Ca (mg/L)	34	39	34	39
PO ₄ (mg/L)	0.4	0.6	0.5	0.5
total PO ₄ (mg/L)	0.8	1.1	0.8	1.2
Al (µg/L)	34	126	29	113
Fe (µg/L)	<5	<5	<5	34
Mn (µg/L)	<3	<3	<3	<3

ments.³ Since the initial LCR monitoring, Chicago has exceeded the lead AL only once, during July–December 1992, with an average 90th percentile compliance monitoring value between 1999 and 2010 of 6 µg/L (SI Table S2).³

The LCR requires 1-L, FD tap samples of water that has stood motionless in the plumbing system (i.e., has stagnated within the plumbing) for at least 6 h. The two variants of the FD sampling protocol currently used by public water systems are defined herein as the NHU first-draw sample, where water is used in a normal household manner, and then allowed to sit motionless in the plumbing for at least 6 h before the sample is collected; and the PF first-draw sample, where the water is run from the sampling tap for a specified amount of time immediately prior to the stagnation period. However, the LCR does not provide specific details on water use during the stagnation period.

Almost all PWSs in the U.S. rely on residents to collect compliance samples under the LCR and there are differences across the U.S. in how systems instruct residents not to use the water during the stagnation period prior to collecting the sample. A review of example sets of sampling instructions provided to residents by large PWSs in the U.S. found that some are instructed not to use any water from the tap to be sampled during the stagnation period. Others are instructed not to use any water in the household. Prior to 2009, CDWM used the PF first-draw sampling protocol, with a 5-min preflush preceding stagnation. Recent instructions to residents included not using water from the sampling tap or from any nearby tap until the (poststagnation) samples were collected, and to collect samples as soon as possible after the minimum required 6-h stagnation period. Regardless of the sampling protocol, resident-collected samples necessitate the use of simple instructions and make it difficult to ensure strict adherence to any sampling protocol. In addition, the diverse premise plumbing materials and configurations (SI Table S1) represent varying effects of flow rates, hydraulic flow characteristics, and possible lead sorption/particle release effects on the shapes of the lead profiles, particularly with corroded galvanized pipe locations.^{4,5}

MATERIALS AND METHODS

Sampling Objectives and Protocol. Since the promulgation of the LCR, new research on lead corrosion has shown that there are many mechanisms and water quality factors

involved.^{1,4,6–11} Specifically, the sampling protocols used in this study were evaluated to determine if

preflushing biases results;
first-draw samples, with or without preflushing, capture the “worst-case” level of lead corrosion under normal use conditions; and
seasonal variability affects lead concentrations (in this water system).

Consistent with the LCR requirements and CDWM compliance sampling, samples for this study were collected by volunteer residents from 32 single-family residences, built between 1890 and 1960, with LSLs. An additional 5 homes were sampled and determined not to have LSLs, and were therefore excluded from further sampling. All results are included in the Supporting Information, but the non-LSL sites were not used in the data analysis (SI Tables S4a, S5, S6a, S6b, and S7).

Information was requested on the specific plumbing configurations of each sampling site to a much greater extent than the regulatory requirements which simply require the plumbing material to be identified. This information, along with analyses conducted for lead, copper, iron, and zinc for each sample, facilitated a better understanding of the observed water lead levels. Residents were asked to (1) complete a plumbing profile identifying the kitchen tap and meter or internal shut-off valve, and (2) describe the internal plumbing, including any recent plumbing work (SI Figure S1). The information provided by residents along with the results of the four metals provided additional information on the sequences of plumbing materials, and the presence of in-line brass plumbing components. CDWM provided the locations of water mains, service line materials, work conducted by the city at each residence (meter installation or repair, shut-off valve repair/replacement, service line leak repair, street excavation), and monthly water use data for residences with water meters. The information provided by CDWM on water main locations was used to measure the distance from the water main to each residence, and internal plumbing information provided by residents was used along with the measured length from the water main to the residence to approximate the LSL length (SI Table S1).

Residents were provided with written sampling and reporting instructions for each sampling event (SI Figures S41–S45). One-liter, high-density polyethylene (HDPE), wide-mouth (5.5 cm, 2.2 in.) sample bottles were used to collect all samples. Residents were instructed not to remove aerators prior to sampling and not to collect samples after point-of-use or point-of-entry treatment devices.

Several prior studies have suggested that significant contributions of particulate-associated lead can be mobilized as a function of flow rate and turbulence in certain water chemistries, though studies have not developed predictive relationships to premise plumbing material, scale composition, and hydraulic flow characteristics.^{6,10–15} To try to achieve the most aggressive high flow conditions under realistic field conditions, residents were instructed to collect all samples by slowly opening the cold water kitchen tap until fully open. Upon receipt, the samples were inspected by EPA for visible particulate matter prior to delivery to the laboratory.

For all first-draw samples, residents were instructed not to use any water throughout the household (i.e., no showering, washing clothes/dishes, flushing toilets, etc.) during the

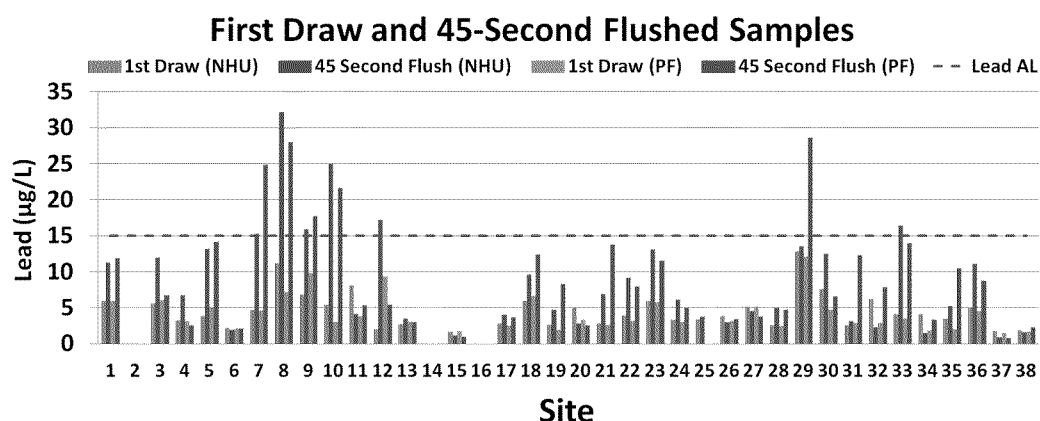


Figure 1. First round lead results for all sites.

minimum mandatory 6-h stagnation period. In this study, PF samples include a flush of at least 5 min prior to the mandatory minimum 6-h stagnation period. A NHU sample had no preflushing prior to the mandatory minimum stagnation period. Residents were instructed to allow the water to sit motionless in the household plumbing a minimum of 6 h, but not more than 24 h, and to record the dates/times the taps were flushed prior to the stagnation period, and the dates/times samples were collected following the stagnation period. First-draw samples using both variants (NHU and PF) were collected in the first and third rounds of monitoring in March/April and September/October, respectively. Additionally, 45-s flushed samples were collected in the first round to evaluate whether a second-draw sample more accurately captured the level of corrosion. Three-min, 5-min, and 7-min flushed samples were collected in the third round of sampling to provide guidance to volunteers when high lead levels were found (SI Table S7). This information can also be used to provide site-specific guidance on minimum flushing times necessary to reduce consumer exposure to lead in drinking water.

In the first round of sampling, each resident collected a NHU first-draw sample and then a second-draw (45-s flushed) sample after allowing the water to run for 45 s. On the second day, residents collected a PF first-draw sample and then a second 45-s flushed sample. EPA's current Public Notification Handbook advises¹⁶ residents to run the water 30 s or until it turns cold before consuming, if the water has not been used for an unspecified "extended period of time", which can result in higher lead levels at the tap for consumers. It has also been previously demonstrated that in some situations, this advice can cause residents to consume the worst-case water sitting stagnant in the LSL.¹⁷ (Figure 1)

Sites 14, 15, 16, and 37 were verified as not having LSLs and were excluded from further sampling. Site 2 was verified as not having a LSL following the June sequential sampling and was excluded from the final round of monitoring. The 45-s flushed sampling was discontinued following the March/April sampling first round due to the presence of severely corroded galvanized pipe in some of the residences (SI Figure S4) which reduced the inner pipe diameter, restricting water flow and resulting in varying volumes of water flowing through the plumbing for the same flush time.

In June 2011, each resident collected a total of twelve PF sequential samples in one day of sampling. The first PF sequential sample was also the PF first-draw sample for the data analysis. All samples were analyzed for lead, copper, zinc, and

iron. The co-occurrence of the metals, along with plumbing details, was used in qualitative assessments to correlate lead results with potential sources of lead in the plumbing network (SI Figure S6).^{4,10}

In September/October 2011, each resident collected a NHU first-draw sample, and a minimum of 11 PF sequential 1-L samples. Sites with high lead levels in the previous rounds collected an additional 3 or 4 PF sequential samples, and one site with a very long LSL (159 ft, 48 m) collected an additional 9 PF sequential samples. The additional PF sequential samples were collected to determine the point at which lead levels consistently dropped below the AL. All samples collected are included in the sampling summary with the numbers and types of samples collected at each site (SI Table S3).

Most stagnation times were relatively consistent across most sites at between 6 and 8.5 h, and all but two sites had stagnation times between 6 and 9 h 10 min, which facilitated unadjusted comparisons (SI Table S6c).

Additional flushed samples were collected in September/October for high lead sites in order to provide residents with guidance on minimizing lead levels in their drinking water. Recommended minimum flushing times were then estimated based on the lead levels and LSL lengths. These results are included in the Supporting Information, but not discussed here.

Sample Analyses. All samples were visually inspected for particulate matter prior to delivery to the EPA Chicago Regional Laboratory. Samples were preserved upon receipt by the laboratory using concentrated nitric acid to pH <2 and held for a minimum of 24 h prior to analysis.¹⁸ The laboratory's Reporting Limits (RL) for lead, copper, and zinc in drinking water samples, using EPA Method 200.8, are 0.5, 1, and 10 µg/L, respectively. The laboratory's RL for iron in drinking water samples, using EPA Method 200.7, is 80 µg/L. Additional laboratory information is included in the Supporting Information.

RESULTS AND DISCUSSION

Both Variants of the First-Draw Protocol Significantly Underestimated Peak Lead Levels, and the NHU First-Draw Protocol Yielded Higher Results Overall than the PF First-Draw Protocol. The 90th percentile lead values for all three rounds of first-draw sampling using both variants were slightly higher than Chicago's historical compliance results, but still fell well below the lead AL (SI Table S4b). Only 2% of the total number of first-draw samples (3 of 151) exceeded the AL despite the presence of lead levels well above the lead action

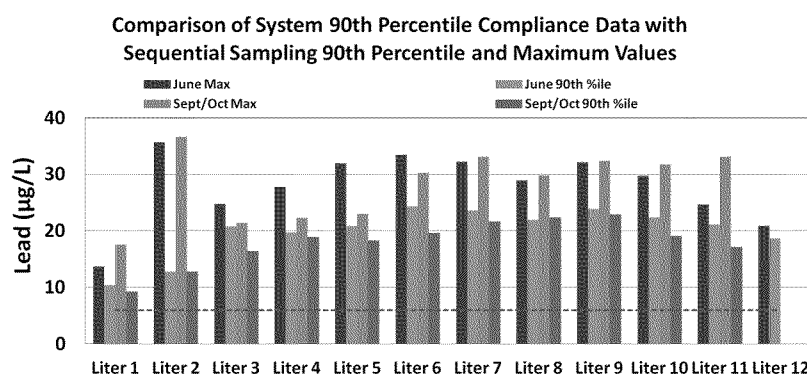


Figure 2. Comparison of 90th percentile LCR compliance data to 90th percentile values from LSL samples (across sites by liter) and maximum values from LSLs. The green dashed line indicates the average 90th percentile compliance monitoring value for Chicago between 1999 and 2010 of 6 $\mu\text{g/L}$.

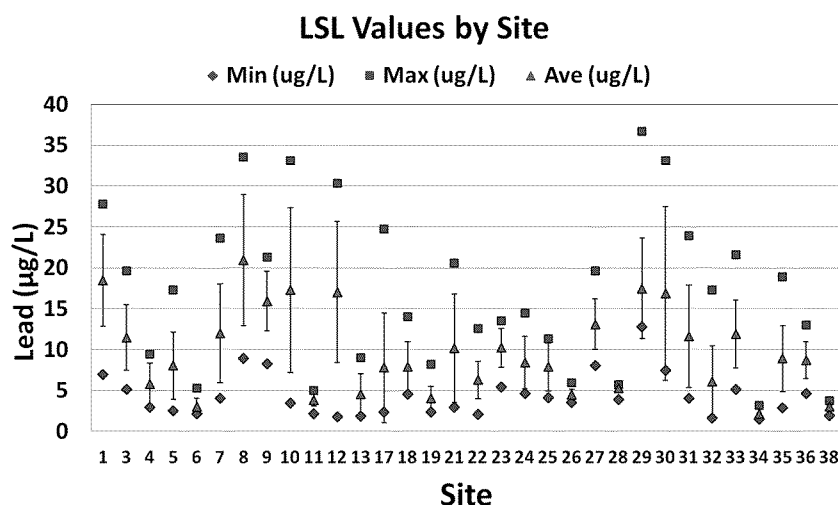


Figure 3. LSL results were highly variable within each LSL and from site to site. Error bars represent 1 standard deviation.

level within the service lines as indicated by the 45-s flushed results in the first round of monitoring and sequential sampling results in the second and third rounds.

In contrast, if the 90th percentile value of each of the successive sequential liter samples from the LSLs is computed across all sampling sites, the lead levels were up to four times higher than Chicago's average 90th percentile value using FD samples. Some peak values for each sequential liter calculated across all sampling sites were over twice the lead AL and up to six times higher than the regulatory compliance data (Figure 2). In summary, 69 of 336 (21%) of the individual sequential samples collected in June and 75 of 319 (24%) of sequential samples in September/October exceeded the lead AL, indicating that current sampling protocols will often considerably underestimate the peak lead levels and overall mobilized mass of waterborne lead in a system with lead service lines.

The NHU results were numerically higher overall than the corresponding PF values for most sites, but the differences were not statistically significant. The PF first-draw protocol produced lower individual results than NHU first-draw protocol in 23 of 32 sample pairs in March/April, and 20 of 27 sample pairs in Sept/Oct (SI Table S4a). Although NHU first-draw samples were collected without directing the residents to flush the tap prior to the stagnation period, NHU can involve showering, washing dishes, or doing laundry a short time prior to the stagnation period, which could clear the lead from the pipes

similar to preflushing the tap. Thus a NHU sample can be effectively the same as a PF sample and yield similar results. Since the sequential sampling results from these same sites show that there is much higher lead present within the LSL at the same time that the NHU and PF first-draw samples were collected, it stands to reason that if the NHU activities were not undertaken, and a larger sample set were used, the NHU samples would yield results that were statistically higher than the corresponding PF samples. The distance from the kitchen tap to the beginning of the LSL was highly variable, ranging from approximately 3 to 87 feet (0.9 to 27 m), and the measured LSL lengths ranged from 43 to 159 feet (13 to 48 m). Consequently, for sites with shorter total plumbing lengths, the initial and final sequential samples would include relatively uncontaminated water from the water main following the 5-min tap preflushing. These samples would contain little to no LSL lead contribution, consistent with plumbosolvency and radial diffusion/flow principles.^{5,19,20} A targeted LSL sampling protocol isolating only LSL contact water would likely yield a higher percentage of results above the lead AL for systems with Pb(II) pipe scale chemistry, but the specific location of the peak lead levels will necessarily vary with premise plumbing configurations.

Seasonal Variability. In a site-by-site comparison, lead concentrations were higher in Sept/Oct than in Mar/Apr or June, with the starkest statistical difference between first-draw

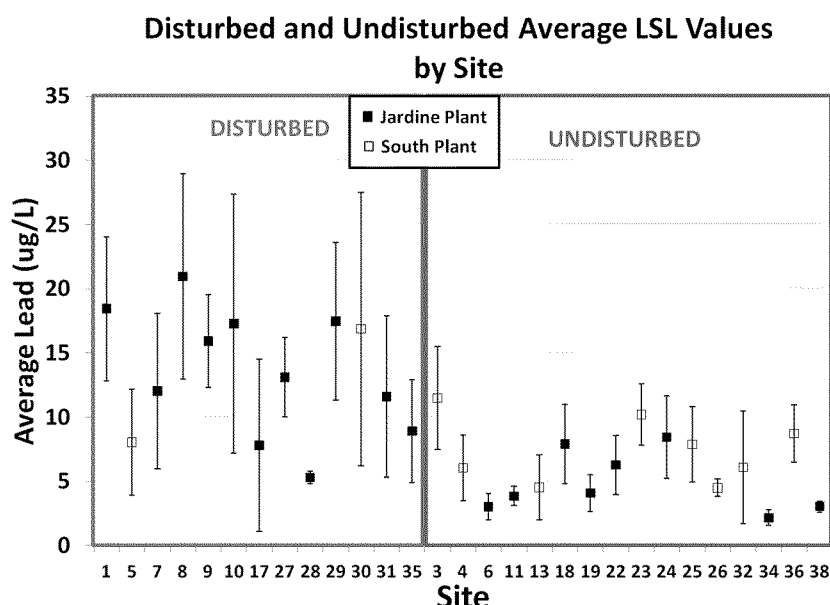


Figure 4. Average lead levels at disturbed and undisturbed sites. Error bars represent 1 standard deviation.

NHU samples collected in Mar/April and Sept/Oct ($p = 0.03$ for two-tailed paired Student's *t*-test). Overall, 68% and 69% of NHU and PF first-draw samples, respectively, were higher in Sept/Oct than in Mar/Apr, while 55% of paired sequential samples were higher in Sept/Oct than in June. Seasonal variation in lead levels consists of multiple contributing factors from the source water through the premise plumbing which could not be precisely isolated in this study, but the results in this study are consistent with other findings on seasonal variability (SI Table S6d).²¹ Factors include (1) water temperature, (2) water chemistry variation, and (3) fluctuations in water usage for Sept/Oct versus June, which could increase or decrease lead levels.^{22,23}

Lead Concentrations Vary Throughout Each Individual LSL and among Different LSLs Across the System. There was a high degree of variability in sequential sample results at most sites, some of which could include a particulate-bound component as reflected in spikes in some sequential sampling results (SI Figures S9–S40). For most sites, no individual sample result from within the LSL can characterize the lead concentrations at the site. Within the complete sampling profile results, lead levels at most sites ranged from well below to well above the AL (Figure 3). Under the LCR, this would mean that a system would meet the action level and have no additional regulatory requirements or would exceed the AL and be required to implement additional requirements, depending on which sample result is selected as the compliance sample. The variability within sites and between sites is similar in trend to that found in several other studies reporting sequential sampling conducted in water systems with different corrosion control strategies and chemistries from CDWM.^{1,4,10,12,14,15,24–27}

Additional compliance data from a second large utility (City B) which exceeded the lead AL and conducted sampling using the temperature change LSL sampling protocol in the LCR,³ yielded similar variability across the system (SI Figure S8 and Table S9). A total of 1975 LSL sites were sampled, with 1762 results (89%) below the lead AL; 128 results (6.5%) from 16 to 30 $\mu\text{g/L}$; 57 results (2.8%) from 31 to 50 $\mu\text{g/L}$; and 28 results (1.4%) between 51 and 580 $\mu\text{g/L}$. This LSL sampling protocol

is similarly vulnerable to low biases, although many results were considerably higher than the AL (SI Figure S8).

Factors Affecting Lead Levels. The majority of high lead results occurred at sites with a documented physical disturbance of the LSL between 2005 and 2011 (Figure 4). The actual extent to which the LSL was physically disturbed is unknown for all sites, and the records of disturbances are based on information provided by CDWM and by the sampling volunteers (SI Figures S9–S40).

For the purpose of this study a physical LSL disturbance is defined as a meter installation or replacement, autometer-reader (AMR) installation, service line leak repair, external service shut-off valve repair or replacement, or significant street excavation directly in front of the home that could disturb the LSL. An “undisturbed” site is an unmetered site where neither the CDWM nor resident have a record or recollection of any disturbance, as defined above. A third category, “indeterminate”, is used for three sites where CDWM has no record of any LSL disturbance, and the resident did not provide a response as to whether there has been any LSL disturbance. Cross-checking was important because information provided by volunteers in some cases contradicted CDWM records, and upon further investigation, the records were found to be incomplete and were corrected, which resulted in reclassification of the site.

Of the 13 disturbed sites, 11 sites had 3 or more sequential sampling results above the lead AL, two sites had 2 results each above the AL, and one site had no results above the AL. Of the 16 sites with no known disturbance, only three sites had any results above the lead AL. In the remaining 3 “indeterminate” sites, 30 of 81 sample results (37%) were above EPA's lead AL (Table 2).

A recent AWWA publication on the state of water infrastructure highlights the need for major infrastructure work.²⁸ This necessary infrastructure work will potentially increase the incidence of damage to the protective scales within LSLs as this work is performed. Inevitably, these physical LSL disturbances will continue to occur with increased frequency as part of daily routine water system maintenance and nonwater related community infrastructure work.

Table 2. Lead Results for Disturbed, Undisturbed, and Indeterminate Sites^a

disturbed sites			undisturbed sites			indeterminate sites		
no. sites	no. samples	no. above AL	no. sites	no. samples	no. above AL	no. sites	no. samples	no. above AL
13	327	117	16	372	6	3	81	30
% samples over AL: 36%			% samples over AL: 2%			% samples over AL: 37%		

^aMost lead results above the AL were found at sites with LSL disturbances. Additional results above the AL were also found at sites where the status of the LSL (disturbed or undisturbed) could not be confirmed. Sites without LSL disturbances had few if any results above the AL.

Possible Implications of Water Conservation and Use. Information provided by CDWM and volunteers anecdotally suggests that low water usage may also play a role in high lead levels at some sites. Of the four locations with the highest average lead levels, three (Sites 1, 29, and 10) had documented low water usage. Site 1 had average monthly water usage of 3444 gallons (13 037 L) which does not appear to be low usage. However, information provided by the resident indicates that the majority of the monthly water usage occurs during a relatively small number of days during the month when there is a high volume of water usage. Site 29 had average monthly usage of 1826 gallons (6912 L), and Site 10 had an average usage of 1438 gallons/month (5443 L/month). For comparison, the mean single-family household water usage is approximately 8582 gallons/month (32 486 L/month), with a sizable standard deviation.²⁹

In two locations (Sites 17 and 5), lead levels decreased with an increase in water usage. As water usage approximately doubled at Sites 17 and 5, maximum lead levels from sequential sampling decreased from 25 to 5.5 µg/L and from 17 to 12 µg/L, respectively. Although this represents a small set of samples, these observations support the idea that higher lead levels can be associated with low water usage.³⁰

Extrapolating from prior research suggests the necessity of consistent flow to deliver corrosion inhibitor effectively into passivating films,³¹ and correlates increased inhibitor dosages with reduced lead release.^{10,32–35} Low water usage may inhibit healing of the damaged scales, and influence the rate of galvanic corrosion. Water usage effects cannot be separated from other seasonal effects in this study, but prior literature and the combined sequential graphs showing entire profiles shifted up or down from the June to Sept/Oct sampling suggest further investigation is warranted (SI Figures S9–S40). As conservation efforts increase, it will become increasingly important to conduct further research on the relationship between water usage and increases in lead levels.

The results in this study also indicate that more appropriate flushing guidance must be developed, based on neighborhood and premise plumbing characteristics, and whether a home has a LSL or not. Much of the current published and web-based flushing guidance inadvertently increases the risk of exposure to elevated lead levels by clearing an insufficient amount of water volume.¹⁷ Even fully flushing LSLs may only lower lead levels to a limiting, measurable lead level, that relates to the plumbosolvency of the water, the flow rate, the length and internal diameter of the pipe,^{5–7,10,19,20} and possibly effects of prior disturbances (SI Table S7).

Risk Identification and Management. Recently, CDC issued a health alert associating higher elevated blood lead levels with partial LSL replacement,³⁶ and also concluded that LSLs were an independent risk factor for elevated blood lead levels even when lead levels in drinking water met the LCR lead AL of 0.015 mg/L.³⁷ As highlighted in this study, LSLs can contribute high lead when they are disturbed in many different ways, not just due to partial LSL replacement, and water usage may also play a role in the resultant high lead levels and potential increased human exposure. In an August 2012 update on lead in drinking water and blood lead levels, the CDC notes that “The recent recommendations from the CDC Advisory Committee on Childhood Lead Poisoning Prevention to reduce or eliminate lead sources for children before they are exposed underscore the need to reduce lead concentrations in drinking water as much as possible”.³⁸

As the ultimate human and environmental health goal, LSLs should be completely removed where possible. The stability of the protective scales within LSLs depends on many factors which can change over time. For example, changes to water quality or treatment have resulted in high lead levels over a sustained period of time (years).^{10,39–41} Under the current regulatory framework, elevated lead levels from disturbances, water quality, treatment, or water usage changes can potentially go undetected for up to 3 years between LCR compliance monitoring periods, which can result in increased public exposure over a significant period of time.

Proper selection of sampling sites, sampling protocol, and other site conditions is critical for evaluating the amount of lead corrosion and release that is occurring in the distribution system. Successful optimization of the plumbosolvency treatment depends on an accurate understanding of the corrosion mechanisms, pipe scale mineralogy and structure, and the consequences of LSL disturbances and water conservation efforts. No published studies could be found that systematically investigated the time and inhibitor doses/water quality adjustments necessary to overcome the disturbances and damage to the lead pipe scales that will be routinely occurring throughout cities across the U.S., as long as full or partial lead service lines remain in service.

Analyses of the Chicago LSL scales by EPA (to be reported elsewhere) reveal that the surface coatings on both lead service line and galvanized interior pipes from CDWM are primarily composed of amorphous aluminum, calcium, and phosphorus-rich deposits, and not crystalline lead(II) (or zinc)-orthophosphate phases that are predicted by conventional divalent lead plumbosolvency theory for orthophosphate dosing.^{10,33,42} An understanding of the scales is essential to study and implement procedures and strategies for effective and timely repair of the protective scales damaged by LSL disturbances, and to minimize the public's exposure to high lead levels that can result from damaging the scales. Experimental evaluations are critical when scale compositions fall outside the scope of well-understood predictive corrosion control practices.

ASSOCIATED CONTENT

* Supporting Information

Additional background information, tabular summaries of sampling results, and graphics. This material is available free of charge via the Internet at <http://pubs.acs.org>.

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Notes

The authors declare no competing financial interest.

ACKNOWLEDGMENTS

We wish to express special thanks to the City of Chicago Department of Water Management for the considerable time and effort put forth in providing information for this project, and to the EPA and HUD volunteers who participated in this study and opened up their homes to make this project possible, as well as the team at the EPA Chicago Regional Laboratory for their work on the sample analyses, and Mostafa Nouredin (EPA) and Kevin Sui (Northwestern University) for their valuable assistance during this project. Any opinions expressed in this paper are those of the authors and do not necessarily reflect the official positions and policies of the EPA.

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Detection and Evaluation of Elevated Lead Release from Service Lines: A Field Study

(Supporting Information for Manuscript ID: es-2013-003636)

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The supporting information provides additional background information, summaries and graphics for the underlying data used in the study.

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Background

The Lead and Copper Rule (LCR) is a treatment technique regulation that requires all public water systems to optimize corrosion control and utilizes tap sampling for lead and copper to determine whether additional actions need to be taken by the system. It is important to note that the sampling conducted under the LCR is not designed to evaluate individual consumers' lead exposure or risk and that the lead action level (AL) was not established as a health-based number. The lead AL is the level which EPA determined in 1991 that systems could feasibly meet, taking into account the available treatment technologies and the cost of those treatment technologies. The lead AL should not be viewed or used as a threshold value to determine whether the water is safe or unsafe to drink, and it should be reiterated that the EPA and CDC have determined that there is no safe level of lead exposure (i.e., no level at which there is not an adverse effect).

Tap sampling conducted under the LCR is intended to measure the amount of lead and copper corrosion that is occurring in public water systems using worst-case site selection and a specified sampling protocol. The sampling protocols in the current LCR were established in 1991, based on the existence of many potential sources of lead throughout the water distribution system, including lead service lines connecting the water main to the homes, leaded-solder used to join copper pipe, and leaded-brass devices, such as meters, brass connectors and shut-off valves, faucets and fixtures. The current LCR sampling requirements are prescriptive and based on the relative significance of lead sources in 1991. The sequential sampling protocol (described below, and in the accompanying paper) that resulted in capturing the highest lead, as well as the sample results themselves, are not allowed to be used in the current compliance calculation.

The LCR utilizes a combination of: worst-case site selection (sites expected to yield the highest lead results); sampling protocols used to capture the highest lead; and repeated sampling at the same sites in order to measure the level of lead corrosion that is occurring throughout the water distribution system. Utilizing this sampling structure allows U.S. EPA to keep the sampling burden on public water systems manageable, while still accomplishing the objectives of the sampling under the LCR. Absent these key components, the number of samples needed to accurately assess system-wide corrosion would necessarily need to increase substantially to accomplish the objectives of the LCR.

The action level for lead is 0.015 mg/L, but is presented here as 15 µg/L for the purpose of using consistent units for the data. An exceedance of the lead AL based on the sampling triggers specific actions that a public water system must undertake to protect public health, such as installing or adjusting corrosion control treatment and providing public education. Additionally, where the corrosion control treatment has proven ineffective at lowering lead levels below the lead AL, the removal of lead service lines is triggered. There are many different corrosion mechanisms and factors that govern lead corrosion. The selection of sampling sites, sampling protocol, and site conditions are essential components for evaluating the level of corrosion that is occurring in the distribution system, regardless of the mechanism(s) or contributing factor(s). It is therefore critically important that the sampling protocol accurately portray the level of corrosion that is occurring.


Lead Service Line and Plumbing Information

As part of the sampling protocol, residents were asked to provide a plumbing profile (figure S1), describing their internal plumbing, and identifying the location of the kitchen tap, and shut-off valve/meter.

Volunteer ID: _____

Home Plumbing and Service Line Diagrams

Below there are 4 diagrams for common household plumbing configurations and the 5th diagram is blank. Please review the diagrams and select the diagram that best matches the plumbing configuration for your home. Each of the diagrams shows where the water service line comes into the home and where the kitchen tap is located. If none of the four diagrams matches your home, use the blank diagram (number 5) to draw where the water service line comes into your home and where your kitchen tap is located. If you do not know where the service line comes into the home, you can note that in your Home Plumbing description below.

Note: Some homes have water meters and some do not. On the diagrams below, if you do not have a water meter, pick the diagram that matches where your service line comes into your home and where the kitchen tap is, and cross out the meter symbol 

Home Plumbing Description: In the space below, please describe your home plumbing as best you can, from the point at which the water service line comes into your home to the location of your kitchen tap (length of pipe, diameter of pipe, pipe material, etc.):

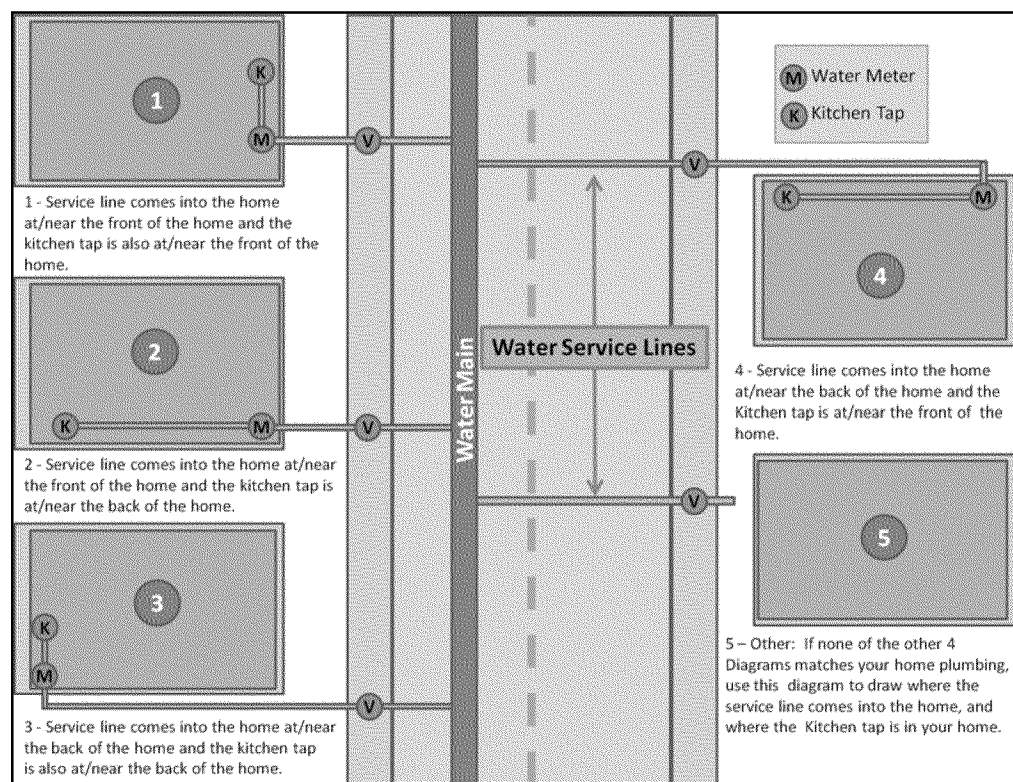


Figure S1: Plumbing Profile Diagram

Table S1 contains a summary of the LSL information for each sampling site. Due to the site-specific plumbing characteristics, the liter which first begins to capture LSL water at each site was expected to be variable, as was the liter which would begin to collect uncontaminated water from the water mains. The study findings regarding whether the current sampling protocol is capturing the corrosion that is occurring are not affected by this limitation.

Site	LSL Length ft (meters)	LSL End Point	Site	LSL Length ft (meters)	LSL End Point
1	89 (27.1)	BFW	22	65 (19.8)	IFW
3	73 (22.3)	IFW	23	66 (20.1)	IFW
4	Unknown	Unknown	24	56 (17.1)	IFW
5	80 (24.4)	IBW	25	70 (21.3)	IFW
6	60 (18.3)	IFW	26	66 (20.1)	IFW
7	59+ (18.0+)	BFW	27	47+ (14.3+)	Unknown
8	57 (17.4)	IFW	28	61+ (18.6+)	Unknown
9	102 (31.1)	BFW	29	159 (48.5)	BFW
10	48+ (14.6+)	IFW	30	49+ (14.9+)	Unknown
11	50 (15.2)	IFW	31	71+ (21.6+)	IFW
12	53 (16.2)	IFW	32	43 (13.1)	IFW
13	49+ (14.9+)	Unknown	33	43+ (13.1+)	IFW
17	58+ (17.7+)	Unknown	34	Unknown	Unknown
18	76 (23.2)	IFW	35	80 (24.4)	BFW
19	63 (19.2)	IFW	36	110 (33.5)	IBW
21	46 (14.0)	IFW	38	51 (15.5)	IFW

IFW = LSL ends just inside the front wall
IBW = LSL ends just inside the back wall
BFW = LSL ends at an unknown distance beyond the front wall
+ = Indicates that the LSL was measured from the water main to the front the home, and it is not known whether the LSL extends beyond the front wall of the home.

Table S1: LSL Lengths – The length of the LSLs for most sites were measured and are presented in this table. The LSLs for two sites (site 4 and site 34) were not measured.

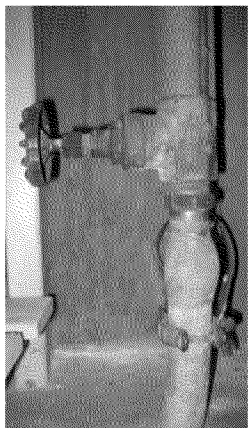


Figure S2: LSL Bulb

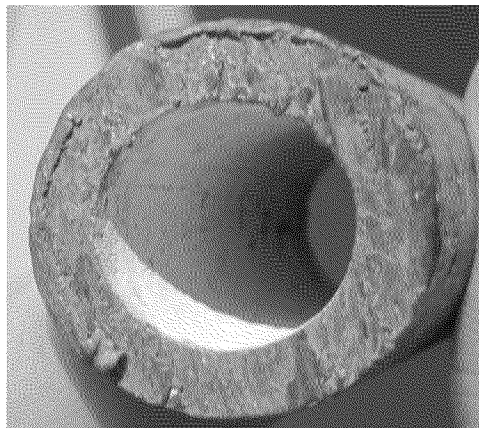


Figure S3: LSL segment (3/4 inch / 1.91 cm diameter)

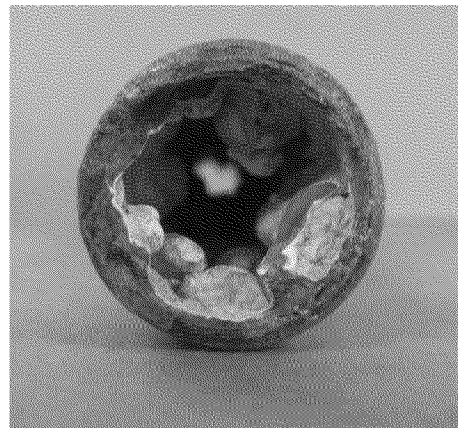


Figure S4: Severely corroded galvanized iron pipe.

Figure S2 shows a typical LSL in Chicago coming up from the foundation of the basement. The lead service line is a dull gray and easily scratched with a key. The soft LSL is typically soldered to the interior (household) plumbing, leaving a characteristic bulb. The LSL can also be connected to household pipe using a brass compression fitting.

Figure S3 is a close-up of a 3/4 inch (1.91 cm) diameter LSL, showing the thickness of a typical LSL.

Figure S4 is a cross-section of a severely corroded galvanized pipe from one of the sample sites. In this photograph the inner diameter is significantly reduced which affects the volume of water that will flow through the pipe in a set amount of time. For homes with corroded galvanized pipe, water will flow slower through the pipe and longer flushing times are generally needed to flush the lead from the plumbing.

City Information

Samples were collected from 32 single-family homes in Chicago with LSLs. Twenty-three homes were in the Jardine Plant service area and nine homes were in the South Plant service area.

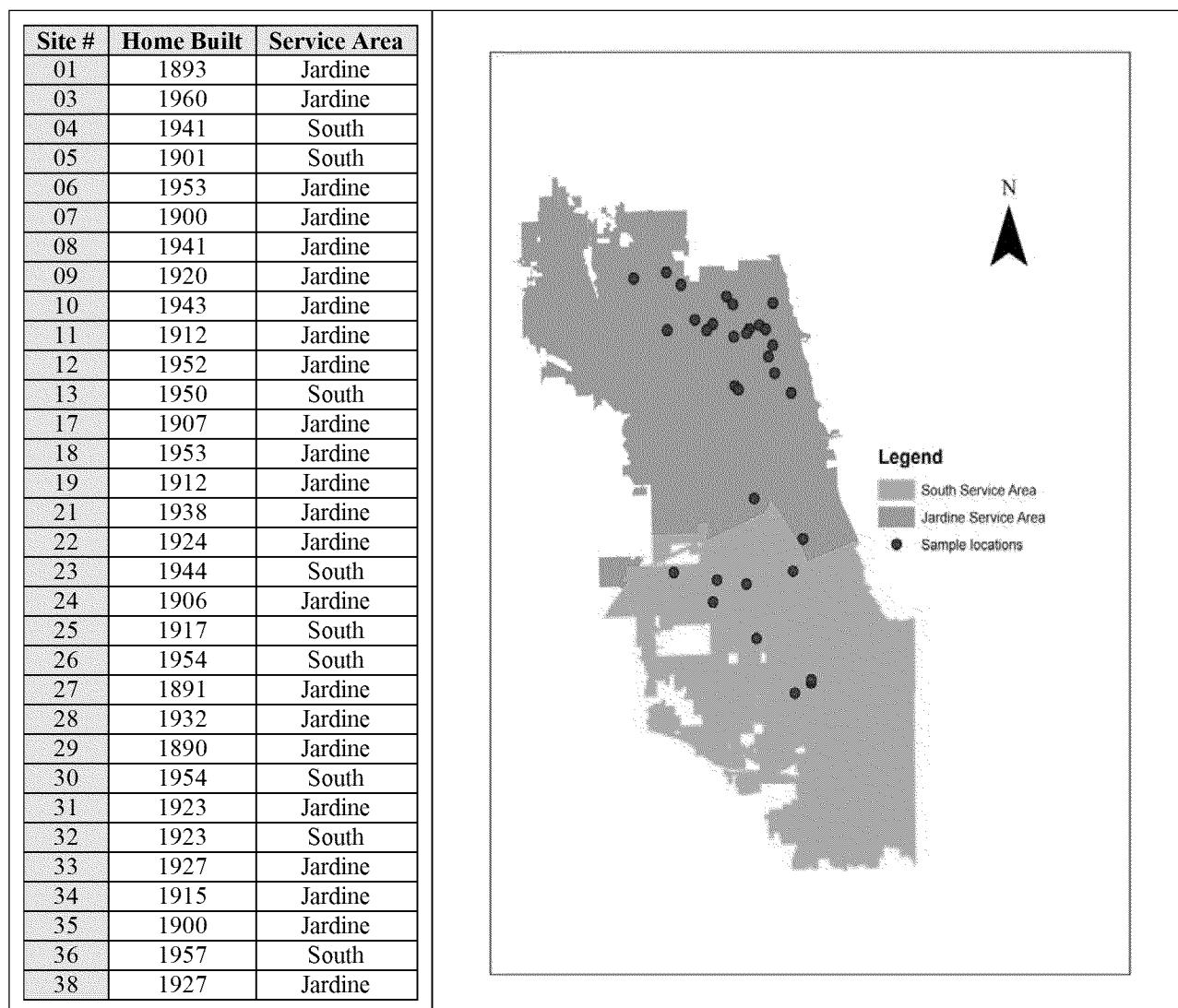


Figure S5: Home age and plant service areas for sampling locations

Table S2 contains a summary of the City's compliance monitoring data for lead. The City exceeded the lead AL only once, during the July-December 1992 compliance monitoring period.

City of Chicago (1992 – 2010) 90 th Percentile Lead Values (µg/L)			
Monitoring Period Begin	Monitoring Period End	Number of Samples	90th Percentile Value
1/1/2008	12/31/2010	50	6
1/1/2005	12/31/2007	50	6
1/1/2002	12/31/2004	50	4
1/1/1999	12/31/2001	50	7
1/1/1999	12/31/1999	50	8
1/1/1998	12/31/1998	53	14
7/1/1997	12/31/1997	100	11
1/1/1997	6/30/1997	100	10
1/1/1993	6/30/1993	100	13
7/1/1992	12/31/1992	120	20
1/1/1992	6/30/1992	100	10

Table S2: City of Chicago 90th Percentile Compliance Values (1992 – 2010)

Laboratory and Analytical Information

All samples were inspected for visible particulates prior to delivery to the laboratory. In light of the significant increase in visible particulate in the final round of monitoring, the presence of fine particulates that would readily dissolve in the nitric acid preservative should not be discounted. Samples collected during the final round of monitoring coincided with the Fire Department's annual valve exercising. Colloidal lead may explain some of the variability in lead levels between the June and Sept/Oct rounds.

Laboratory blanks, laboratory fortified blanks and laboratory fortified samples were run at a frequency of at least one per twenty samples. Laboratory blanks run with the samples did not have any detections of lead above the reporting limit and all Laboratory fortified blanks and laboratory fortified samples had recoveries greater than 90%.

All laboratory instrumentation was inspected and maintained according to Chicago Regional Laboratory maintenance protocols, and calibrated daily according to Chicago Regional Laboratory standard operating procedures.

The Chicago Regional Lab Quality Assurance (QA) Contact performed a data quality assessment on the results based on laboratory blanks, laboratory fortified blanks and matrix spikes. The QA Contact identified no biases in the sample results due to these quality control measurements.

Sampling Summaries

Sample site summary table - A summary table of the types of samples collected at each site, for each sampling protocol is presented in Table S3 below. The highlighted rows for Sites 2,

14, 15, 16 & 37 were confirmed not to have LSLs and Site 20 is the same residence as Site 21 (Kitchen tap and bathroom tap). Following the first round of sampling, Site 20 (bathroom tap) was no longer sampled, to maintain consistency of using kitchen taps across all sites. Only sample results from LSL sites are presented and analyzed in the study paper. The first liter of the sequential samples in June and Sept/Oct also serve as the PF first-draw samples.

Summary of Samples Collected at Each Site							
Site #	Total # Samples	Mar/April		June	Sept/Oct		
		Day 1	Day 2	Day 1	Day 1	Day 2	Day 3
01	34	A, C	B, D	E-12 samples	A	E-14 samples	F, G, H
02	16	A, C	B, D	E-12 samples	DNS	DNS	DNS
03	30	A, C	B, D	E-12 samples	A	E-11 samples	F, G
04	16	A, C	B, D	E-11 samples	DNS	DNS	DNS
05	28	A, C	B, D	E-12 samples	A	E-11 samples	DNS
06	28	A, C	B, D	E-12 samples	A	E-11 samples	DNS
07	35	A, C	B, D	E-12 samples	A	E-15 samples	F, G, H
08	35	A, C	B, D	E-12 samples	A	E-15 samples	F, G, H
09	30	A, C	B, D	E-12 samples	A	E-11 samples	F, G
10	34	A, C	B, D	E-12 samples	A	E-14 samples	F, G, H
11	30	A, C	B, D	E-12 samples	A	E-11 samples	F, G
12	34	A, C	B, D	E-12 samples	A	E-14 samples	F, G, H
13	16	A, C	B, D	DNS	A	E-11 samples	DNS
14	4	A, C	B, D	DNS	DNS	DNS	DNS
15	4	A, C	B, D	DNS	DNS	DNS	DNS
16	4	A, C	B, D	DNS	DNS	DNS	DNS
17	34	A, C	B, D	E-12 samples	A	E-14 samples	F, G, H
18	30	A, C	B, D	E-12 samples	A	E-11 samples	F, G
19	27	A, C	B, D	E-12 samples	DNS	E-11 samples	DNS
20	4	A, C	B, D	DNS	DNS	DNS	DNS
21	28	A, C	B, D	E-12 samples	A	E-11 samples	DNS
22	28	A, C	B, D	E-12 samples	A	E-11 samples	DNS
23	30	A, C	B, D	E-12 samples	A	E-11 samples	F, G
24	33	A, C	B, D	E-12 samples	A	E-14 samples	F, G
25	16	A, C	B, D	E-12 samples	DNS	DNS	DNS
26	30	A, C	B, D	E-12 samples	A	E-11 samples	F, G
27	33	A, C	B, D	E-12 samples	A	E-14 samples	F, G
28	30	A, C	B, D	DNS	A	E-11 samples	F, G
29	40	A, C	B, D	E-12 samples	A	E-20 samples	F, G, I
30	18	A, C	B, D	DNS	A	E-11 samples	F, G
31	31	A, C	B, D	E-12 samples	A	E-12 samples	F, G
32	28	A, C	B, D	E-12 samples	A	E-11 samples	DNS
33	33	A, C	B, D	E-12 samples	A	E-14 samples	F, G
34	18	A, C	B, D	DNS	A	E-11 samples	F, G
35	30	A, C	B, D	E-12 samples	A	E-11 samples	F, G
36	30	A, C	B, D	E-12 samples	A	E-11 samples	F, G
37	4	A, C	B, D	DNS	DNS	DNS	DNS
38	16	A, C	B, D	E-12 samples	DNS	DNS	DNS

A = NHU First-draw Sample
B = PF First-draw Sample
C = NHU 45-Second Flushed Sample
D = PF 45-Second Flushed Sample
E = Sequential Sample

F = 3-minute Flushed Sample
G = 5-minute Flushed Sample
H = 7-minute Flushed Sample
I = 10-minute Flushed Sample
DNS = Site did not sample

Table S3: Summary of samples collected at each site using each sampling protocol.

First-draw and 45-second flushed samples – Results for first-draw and 45-second flushed samples using the normal household use (NHU) and pre-flushed (PF) sampling protocols are presented in Table S4 below.

In addition to the first-draw samples, a 45-second flush sample was collected by running the water for 45 seconds immediately following the collection of the NHU first-draw and PF first-draw samples during the March/April sampling. Overall, the 45-second flush sample results were higher than the first-draw results, and yielded a higher percentage of results above the lead AL. A total of 32 NHU/45-second flushed and 32 PF/45-second flushed samples were collected, with 6 NHU 45-second flushed results above the lead AL (19%), and 5 PF/45-second flushed results above the AL (16%). The total number of 45-second flush sample results above the lead AL was 11 of 64 (17%); a percentage significantly higher than the first-draw results (2%).

First-draw and 45-second Flushed Sample Lead Results (µg/L)							
Site	A (Mar/Apr)	C (Mar/Apr)	B (Mar/Apr)	D (Mar/Apr)	B (June)	A (Sept/Oct)	B (Sept/Oct)
1	5.93	11.3	5.94	11.9	6.98	7.37	9.19
3	5.60	12.0	6.01	6.71	5.82	10.0	8.28
4	3.25	6.76	3.12	2.56	3.61	DNS	DNS
5	3.84	13.2	4.97	14.1	2.56	3.04	2.76
6	2.31	1.90	2.07	2.13	2.50	2.44	2.25
7	4.74	15.3	4.62	24.9	4.91	5.12	4.03
8	11.2	32.2	7.12	28.0	11.1	17.5	9.24
9	6.82	15.9	9.80	17.7	10.4	15.3	8.29
10	5.46	25.0	3.06	21.6	3.70	4.98	3.46
11	8.08	4.13	3.85	5.30	2.15	3.53	2.96
12	1.99	17.2	9.36	5.45	1.80	2.27	5.35
13	2.68	3.50	3.05	2.94	DNS	2.53	1.88
17	2.83	4.00	2.50	3.70	2.37	2.65	2.73
18	5.98	9.57	6.60	12.4	4.55	5.80	4.75
19	2.59	4.69	1.92	8.27	2.90	DNS	3.01
21	2.81	6.87	2.60	13.8	3.16	4.13	2.99
22	3.91	9.19	3.36	7.93	2.06	3.21	2.29
23	5.97	13.1	5.80	11.5	8.30	9.16	7.02
24	3.33	6.10	3.05	4.98	4.63	7.57	6.62
25	3.41	3.75	ND	ND	4.28	DNS	DNS
26	3.89	3.02	3.12	3.45	3.51	4.53	4.88
27	5.19	4.53	5.36	3.76	8.06	8.30	12.6
28	2.51	4.99	2.47	4.70	DNS	4.26	3.94
29	12.8	13.5	12.1	28.6	13.7	1.9	17.6
30	7.56	12.5	4.72	6.52	DNS	8.39	7.88
31	2.53	3.16	2.92	12.3	4.03	4.67	5.97
32	6.18	2.29	2.90	7.82	3.08	3.36	2.94
33	4.25	16.4	3.51	14.0	5.18	5.55	5.52
34	4.12	1.51	1.88	3.30	DNS	2.07	1.52
35	3.53	5.28	2.04	10.5	2.86	5.02	3.44
36	5.11	11.1	4.56	8.76	5.02	5.88	4.61
38	1.87	1.60	1.66	2.30	1.92	DNS	DNS
Ave	4.76	9.23	4.25	9.74	4.82	5.73	5.45
n	32	32	32	32	28	28	29
A = NHU First-draw Sample B = PF First-draw Sample C = NHU 45-Second Flushed Sample				D = PF 45-Second Flushed Sample DNS = Site did not sample n = number of samples collected			

Table S4a: First-Draw and 45-Second Flushed Sampling Results. Samples that were above the lead AL are in bold, and samples that contained visible particulates are shaded yellow.

Summary of NHU and PF First-Draw Results					
	NHU (Mar/Apr)	PF (Mar/Apr)	PF (June)	NHU (Sept/Oct)	PF (Sept/Oct)
90th %ile Pb Value (µg/L)	8	7	8	10	9
No. of Samples	32	32	28	29	30
No. > AL	0	0	0	2	1

Table S4b: Comparison of LCR-equivalent 90th percentile results using alternative first-draw protocols.

Sequential sampling results (June 2011) – The sequential sampling approach provided a more reliable (volumetric) method for assessing corrosion as compared to a flushed (time-based) approach. Attempting to characterize the flow at each site would require an evaluation of the plumbing materials and dimensions, as well as the condition of the plumbing materials at each site, is not a feasible or reliable protocol for compliance monitoring.

The results of the each liter in the sequential sampling conducted in June are tabulated below in Table S5 by site.

June Sequential Sampling Results by Site/Liter (µg/L)												
Site	Liter											
	1	2	3	4	5	6	7	8	9	10	11	12
01	6.98	10.5	24.8	27.8	27.5	24.3	22.6	17.8	19.5	20.0	21.1	19.6
03	5.82	8.91	9.18	10.2	13.1	14.6	14.4	12.9	12.1	11.6	10.7	9.34
04	3.61	5.56		7.17	8.90	9.41	8.78	8.30	5.14	3.59	3.11	2.96
05	2.56	6.73	14.0	17.3	16.5	9.85	6.72	6.29	6.01	5.73	5.65	5.60
06	2.50	2.23	2.28	2.57	2.44	2.75	2.65	2.59	3.57	5.26	4.67	4.80
07	4.91	5.45	6.28	6.73	7.03	22.9	23.6	19.7	16.3	16.2	16.7	14.6
08	11.1	12.8	21.6	19.7	32.0	33.5	32.2	28.9	32.1	29.7	24.2	18.7
09	10.4	18.0	20.8	20.0	17.9	17.0	15.8	14.7	14.3	12.9	11.5	9.48
10	3.70	5.20	5.39	6.49	14.9	23.6	22.4	21.9	23.9	20.2	20.7	20.9
11	2.15	2.58	2.76	2.97	3.36	3.61	3.73	3.82	4.28	4.11	4.11	4.43
12	1.80	2.95	3.55	6.69	20.9	26.9	25.7	25.1	24.9	22.4	15.9	7.80
17	2.37	8.46	7.12	7.20	7.27	10.5	9.91	9.56	22.6	23.3	24.7	6.30
18	4.55	5.73	5.12	6.43	5.41	5.62	5.5	9.38	14.0	12.1	11.3	11.6
19	2.90	2.62	2.41	8.22	4.58	3.16	4.02	5.07	4.57	4.06	3.31	2.82
21	3.16	3.12	3.08	2.97	13.0	20.6	18.7	16.4	16.3	14.2	6.78	3.21
22	2.06	2.82	5.11	5.42	6.89	12.6	7.80	7.11	6.52	6.55	7.55	7.45
23	8.30	9.06	11.1	13.5	13.2	12.4	11.7	11.0	9.55	7.16	5.69	5.41
24	4.63	6.06	6.43	5.24	5.06	4.91	5.02	8.21	11.9	12.6	11.9	12.2
25	4.28	4.28	4.15	4.23	6.82	10.9	11.3	10.9	10.1	9.68	9.17	8.82
26	3.51	3.83	3.99	3.93	3.86	3.99	4.00	4.01	4.12	4.39	4.30	4.23
27	8.06	9.13	9.84	10.3	10.4	11.4	13.10	13.9	14.2	13.3	12.2	10.1
29	13.7	35.7	18.8	17.7	16.8	16.5	16.6	15.7	14.4	14.1	13.7	13.4
31	4.03	5.03	5.14	6.17	13.1	15.4	15.6	16.3	20.8	18.8	7.91	4.48

June Sequential Sampling Results by Site/Liter (µg/L)												
Site	Liter											
	1	2	3	4	5	6	7	8	9	10	11	12
32	3.08	2.29	2.07	2.28	6.95	15.5	9.91	9.27	8.30	6.12	2.60	1.65
33	5.18	6.85	10.0	7.74	9.61	13.9	16.4	13.5	12.3	13.7	10.7	9.95
35	2.86	7.89	12.9	11.9	9.85	8.59	7.28	6.82	6.23	5.34	5.02	4.83
36	5.02	6.90	7.68	8.46	9.90	9.81	9.51	9.34	9.19	8.93	9.20	9.19
38	1.92	3.04	3.06	3.04	2.91	3.03	3.12	3.07	3.36	3.21	3.04	3.76
Min	1.80	2.23	2.07	2.28	2.44	2.75	2.65	2.59	3.36	3.11	2.60	1.65
Max	13.7	35.7	24.8	27.8	32.0	33.5	32.2	28.9	32.1	29.7	24.7	20.9
Ave	4.83	7.28	8.42	9.07	11.1	13.1	12.4	11.7	12.5	11.7	10.3	8.50
90 th %ile	10.4	12.8	20.8	19.7	20.9	24.3	23.6	21.9	23.9	22.4	21.1	18.7

Table S5: Summary of June Sequential Sampling Results. Samples that were above the lead AL are in bold, and samples that contained visible particulates are shaded yellow.

Sequential Sampling Results (September and October 2011) – The results of the each liter in the sequential sampling conducted in September and October are tabulated below in Table S6 by site. Considerably more sample results contained visible particulates than in previous rounds. The presence of particulates may be a result of the Chicago Fire Department exercising valves during the time period when samples were being collected.

All sites collected at least 11 sequential samples, and some sites with high sample results in June collected additional samples. The additional sequential sample results are included here but were not included in the data analyses, since extra samples were collected only from sites with high lead. A review of the data, including and excluding these additional results was performed to ensure that a bias has not been introduced, and the review indicates that the study findings are not significantly affected by including or excluding the data. With the additional 39 samples included, a total of 80 of 358 sample results (22%) exceeded the lead AL. Using only samples 1 through 11 from each site, a total of 75 of 319 sample results (24%) exceeded the lead AL. For the purpose of the data analyses, the first liter sample from the sequential samples in June and Sept/Oct also serve as the first-draw PF sample.

Sept/Oct Sequential Sampling Results by Site/Liter (µg/L)											
Site	Liter										
	1	2	3	4	5	6	7	8	9	10	11
01	9.19	12.8	21.4	22.3	22.0	19.6	16.5	15.6	14.5	14.2	13.8
03	8.28	5.58	5.17	6.43	8.46	14.9	19.6	16.4	15.4	14.3	17.1
05	2.76	10.8	12.2	10.9	12.3	7.21	5.49	5.24	4.65	5.30	5.40
06	2.25	2.18	3.43	2.37	2.30	2.28	2.81	2.32	2.20	4.16	5.03
07	4.03	4.27	5.74	5.75	9.87	15.1	15.3	15.2	12.1	14.8	13.9
08	9.24	8.95	9.45	11.8	18.3	25.0	22.7	22.3	22.9	19.1	15.8
09	8.29	20.0	18.8	21.3	20.0	17.6	16.3	15.7	14.6	14.8	16.1
10	3.46	6.27	6.23	5.05	14.8	21.4	33.1	29.8	32.4	28.1	27.7
11	2.96	4.05	3.90	3.91	4.30	4.44	4.35	4.71	5.02	4.75	4.47
12	5.35	15.7	16.4	19.8	23.0	30.3	25.7	22.4	19.0	17.3	12.2
13	1.88	7.73	9.01	3.57	2.53	3.85	2.96	2.17	2.85	7.55	5.74
17	2.73	2.38	5.45	4.41	4.07	4.09	3.72	3.42	3.35	3.42	3.17
18	4.75	5.09	4.91	5.53	4.81	8.17	8.61	8.67	11.6	11.6	11.4
19	3.01	3.07	2.75	3.80	3.25	3.37	5.80	6.01	6.15	5.18	3.83
21	2.99	3.35	3.03	3.04	16.8	18.2	16.1	13.2	14.9	15.0	5.24
22	2.29	2.86	5.60	5.39	6.32	8.49	7.42	7.20	6.64	7.09	7.36
23	7.02	8.00	8.99	11.0	12.5	12.1	12.8	11.8	10.5	12.1	10.1
24	6.62	8.84	7.30	6.38	6.45	6.59	6.82	10.6	14.5	13.2	12.8
26	4.88	4.61	4.52	4.46	4.52	4.26	5.18	5.40	5.94	5.72	5.82
27	12.6	12.4	12.2	12.5	12.5	13.1	16.3	18.0	18.9	19.6	17.3
28	3.94	5.58	5.39	5.32	5.39	5.11	5.73	5.65	5.30	5.49	5.55
29	17.6	36.7	18.3	17.3	16.6	15.9	15.9	14.3	16.2	12.8	13.2
30	7.88	7.46	8.67	9.54	9.09	11.0	12.9	22.9	31.3	31.8	33.1
31	5.97	5.82	5.20	6.72	15.6	13.4	17.3	18.5	23.9	16.3	5.70
32	2.94	2.24	2.03	2.22	5.50	17.3	9.42	9.07	8.63	7.64	3.50
33	5.52	6.26	12.8	9.09	12.0	14.1	21.6	16.6	16.5	15.8	14.1
34	1.52	1.72	1.69	1.62	1.73	2.66	2.91	2.87	3.17	2.10	1.90
35	3.44	7.42	14.6	18.9	16.0	12.5	10.1	9.56	7.60	8.18	7.21
36	4.61	5.01	5.51	6.11	13.0	11.6	10.3	10.4	10.9	10.3	9.93
Min	1.52	1.72	1.69	1.62	1.73	2.28	2.81	2.17	2.20	2.10	1.90
Max	17.6	36.7	21.4	22.3	23.0	30.3	33.1	29.8	32.4	31.8	33.1
Ave	5.45	7.83	8.30	8.50	10.5	11.9	12.2	12.0	12.5	12.0	10.6
90 th %ile	9.19	12.8	16.4	18.9	18.3	19.6	21.6	22.3	22.9	19.1	17.1

Table S6a: Summary of September/October sequential sampling results used in data analyses. Samples that were above the lead AL are in bold, and samples that contained visible particulates are shaded yellow.

Sept/Oct Sequential Sampling Results by Site/Liter (µg/L)									
Site	Liter								
	12	13	14	15	16	17	18	19	20
01	13.9	14.1	11.7	--	--	--	--	--	--
03	--	--	--	--	--	--	--	--	--
05	--	--	--	--	--	--	--	--	--
06	--	--	--	--	--	--	--	--	--
07	12.7	9.29	6.52	6.03	--	--	--	--	--
08	12.8	9.34	7.93	6.27	--	--	--	--	--
09	--	--	--	--	--	--	--	--	--
10	--	27.1	21.1	10.7	--	--	--	--	--
11	--	--	--	--	--	--	--	--	--
12	6.98	3.28	2.04	--	--	--	--	--	--
13	--	--	--	--	--	--	--	--	--
17	2.84	2.62	2.59	--	--	--	--	--	--
18	--	--	--	--	--	--	--	--	--
19	--	--	--	--	--	--	--	--	--
21	--	--	--	--	--	--	--	--	--
22	--	--	--	--	--	--	--	--	--
23	--	--	--	--	--	--	--	--	--
24	12.8	15.3	15.4	--	--	--	--	--	--
26	--	--	--	--	--	--	--	--	--
27	16.0	12.8	9.24	--	--	--	--	--	--
28	--	--	--	--	--	--	--	--	--
29	11.1	10.1	9.21	9.01	9.29	8.99	8.77	8.73	8.39
30	--	--	--	--	--	--	--	--	--
31	4.17	--	--	--	--	--	--	--	--
32	--	--	--	--	--	--	--	--	--
33	12.4	11.5	10.1	--	--	--	--	--	--
34	--	--	--	--	--	--	--	--	--
35	--	--	--	--	--	--	--	--	--
36	--	--	--	--	--	--	--	--	--
Min	2.84	2.62	2.04	6.03	9.29	8.99	8.77	8.73	8.39
Max	16.0	27.1	21.1	10.7	9.29	8.99	8.77	8.73	8.39
Ave	10.6	11.5	9.58	8.00	9.29	8.99	8.77	8.73	8.39
90 th %ile	13.9	15.3	15.4	10.7	9.29	8.99	8.77	8.73	8.39

Table S6b: Summary of Supplemental September/October sequential sampling results not used in data analyses. Samples that were above the lead AL are in bold, and samples that contained visible particulates are shaded yellow.

Stagnation Times – Volunteers were asked to record the date and time water was last used, and the date and time when sampling began for each set of samples. Table S6c is a summary table which contains the stagnation times for the sequential samples, which is the amount of time the water sat motionless in the household prior to sample collection.

Sample Collection Stagnation Times			
June Sequential Sampling		Sept/Oct Sequential Sampling	
Site	Stagnation Time (hrs:mins)	Site	Stagnation Time (hrs:mins)
1	6:32	1	8:04
3	7:13	3	7:45
4	7:06	5	7:45
5	7:00	6	8:00
6	9:10	7	7:13
7	7:24	8	6:05
8	7:35	9	7:20
9	8:15	10	***
10	6:06	11	7:08
11	7:00	12	6:26
12	8:06	13	***
17	6:25	17	6:55
18	8:43	18	12:53
19	6:30	19	***
21	6:15	21	6:00
22	6:20	22	6:15
23	7:45	23	9:00
24	8:33	24	7:01
25	8:32	26	7:00
26	7:00	27	7:45
27	7:00	28	8:00
29	***	29	***
31	7:26	30	10:45
32	7:13	31	7:30
33	7:02	32	6:54
35	7:04	33	9:06
36	7:45	34	7:05
38	7:13	35	6:55
		36	8:47
***Volunteer did not record date/time the water was last used, but said it was the day before and was at least 6 hours before sampling.			

Table S6c: Summary of stagnation times for sequential sampling.

Seasonal Variability – Table S6d contains a site by site comparison of lead concentrations.

Seasonal Variability (Spring vs. Fall & Summer vs. Fall)					
First-Draw NHU	Sept/Oct > Mar/Apr	First-Draw PF	Sept/Oct > Mar/Apr	Sequential Samples	Sept/Oct > June
No. of Sample Pairs	28	No. of Sample Pairs	29	No. of Sample Pairs	285
No. Higher in Sept/Oct	19	No. Higher in Sept/Oct	20	No. Higher in Sept/Oct	156
% Higher in Sept/Oct	68%	% Higher in Sept/Oct	69%	% Higher in Sept/Oct	55%
First-Draw Samples: Mar/Apr vs. Sept/Oct (Same Site, Same First-Draw Protocol Compared)					
Sequential Samples: June vs. Sept/Oct (Same Site/Same Liter Compared)					

Table S6d: Seasonal variability effects observed.

Flushed sample results – The results of the flushed samples collected in September and October are tabulated in Table S7 by site. Most sites collected a 3 minute and 5 minute flushed sample. Some sites collected a 3, 5, and 7 minute flushed sample; and one site (site 29) collected a 3, 5, and 10 minute flushed sample, due to the length of the service line (159 ft / 48.5 m).

A flushed sample is collected by fully opening the sample tap and letting the water run for at least five minutes prior to a minimum 6 hour stagnation period. The date and time of the PF was recorded. After the minimum 6 hour stagnation period, and immediately before beginning the flushed sample collection, the date and time were again recorded and used as the start of sampling. The 3, 5, 7 and 10 minutes are measured from that start time, and water was not turned off between samples. For sequential sampling and flushed samples, the water was not turned off between samples.

EPA's current Public Notification Handbook includes instructions that advise residents to run the water between 30 and 45 seconds before collecting water for consumption if the water has not been used for an extended period of time. Running the water (flushing) for 45 seconds resulted in high lead levels at the tap for some sites. The flushed sampling results in this study indicate that EPA should develop a more appropriate flushing guidance, based on whether a home has a LSL or not, and the length of the LSL.

For homes with long LSLs, such as Site 29 (159 ft / 48.5 m), flushing may not be a practical way to reduce lead levels, as lead levels did not decline any further following 3, 5 and 10 minutes of flushing. In the case of site 29, residents would likely have a minimum of approximately 8 to 11 µg/L of lead in the drinking water for all water consumed, and should consider installing a water filter or using bottled water for drinking and cooking.

Flushed Sample Summary Table (µg/L)						
	Mar/Apr 2011	Mar/Apr 2011	Sept/Oct 2011	Sept/Oct 2011	Sept/Oct 2011	Sept/Oct 2011
Site	NHU 45sec	PF 45sec	3min	5min	7min	10min
01	11.3	11.9	6.48	6.56	6.97	
03	12.0	6.71	3.78	2.93		
04	6.76	2.56				
05	13.2	14.1				
06	1.90	2.13				
07	15.3	24.9	5.49	5.46	5.32	
08	32.2	28.0	8.25	5.54	5.71	
09	15.9	17.7	14.3	7.23		
10	25.0	21.6	4.95	4.30	4.09	
11	4.13	5.30	1.75	1.69		
12	17.2	5.45	1.78	1.45	1.33	
13	3.50	2.94				
17	4.00	3.70	2.88	2.76	2.86	
18	9.57	12.4	4.15	3.71		
19	4.69	8.27				
20	2.80	2.54				
21	6.87	13.8				
22	9.19	7.93				
23	13.1	11.5	5.64	4.54		
24	6.10	4.98	6.38	12.4		
25	3.75	ND				
26	3.02	3.45	5.06	3.23		
27	4.53	3.76	15.0	14.1		
28	4.99	4.70	4.82	3.26		
29	13.5	28.6	11.9	10.9		10.8
30	12.5	6.52	5.80	4.82		
31	3.16	12.3	3.78	3.76		
32	2.29	7.82				
33	16.4	14.0	4.40	4.06		
34	1.51	3.30	1.83	1.75		
35	5.28	10.5	5.53	4.03		
36	11.1	8.76	7.19	5.29		
38	1.60	2.30				
NHU 45sec Samples were collected following the collection of the First-Draw NHU samples by running the water for 45 seconds following the collection of the First-Draw NHU sample.						
PF 45sec Samples were collected following the collection of the First-Draw PF samples by running the water for 45 seconds following the collection of the First-Draw PF sample.						
3min, 5min, 7min, and 10min flushed samples were collected after pre-flushing the tap for at least 5 minutes prior to the minimum 6 hour stagnation time during which no water was used in the home. Following the stagnation period and prior to sample collection, residents flushed the tap for 3 min to collect the 3min sample, and then an additional 2min for the 5min sample or 4min for the 7min sample. One site (site 29) had the longest lead service line so this site collected a 3 min, 5 min and 10min flushed sample (water was flushed for an additional 5 minutes following the collection of the 5min sample to collect the 10 min flushed sample). Water was not turned off in between samples to avoid the water hammer effect. Residents were instructed to have the bottles ready to insert under the faucet at the appropriate time.						
Site 20 and Site 21 are the same residence. Site 20 was the upstairs bathroom and Site 21 was the kitchen sink. Note that neither the 45sec NHU nor PF samples from the upstairs tap captured any LSL water, while at least one of the kitchen tap samples did.						

Table S7: Summary table of flushed sample results. Samples that were above the lead AL are in bold, and samples that contained visible particulates are shaded yellow.

Classification of Disturbed LSL Sites – A summary of the classification of each site as “disturbed”, “undisturbed”, or “indeterminate” is presented in Table S8, along with the number of samples collected per site and the number and percentage of sample results above the lead action level. The results from the “disturbed” and “undisturbed” sites are consistent with other research efforts showing that LSL disturbances result in higher lead levels^[1-3].

Disturbed, Undisturbed and Indeterminate Site Summary								
Disturbed Sites	Total Samples Collected	# Samples Above AL (Disturbed)	Undisturbed Sites	Total Samples Collected	# Samples above AL (Undisturbed)	Indeterminate Sites	Total Samples Collected	# Samples above AL (Indeterminate)
01	27	16	03	27	4	12	27	17
05	27	2	04	14	0	21	27	7
07	27	11	06	27	0	33	27	6
08	27	19	11	27	0	---	---	---
09	27	15	13	15	0	---	---	---
10	27	15	18	27	0	---	---	---
17	27	3	19	27	0	---	---	---
27	27	5	22	27	0	---	---	---
28	15	0	23	27	0	---	---	---
29	27	15	24	27	0	---	---	---
30	15	4	25	14	0	---	---	---
31	27	10	26	27	0	---	---	---
35	27	2	32	27	2	---	---	---
---	---	---	34	15	0	---	---	---
---	---	---	36	27	0	---	---	---
---	---	---	38	16	0	---	---	---
Totals	327	117	Totals	371	6	Totals	81	30
% of samples above AL:		36%	% of samples above AL:		2%	% of samples above AL:		37%

Table S8: Summary Table of Disturbed, Undisturbed and Indeterminate Sites, with the number and percentages of sample results above the lead AL for each site and each grouping.

Many direct LSL disturbances are localized to a specific segment of the LSL, and yet some sites have higher lead levels in sample liters over a significant portion of the LSL, not just in the immediate area of the LSL that was disturbed. A probable reason is that, except for the initial liter of water, each subsequent one-liter sample reflects both lead levels within the segment of the plumbing where the water stagnated as well as a contribution from the rest of the plumbing the water travelled through. For example, the fifth liter of water collected from a kitchen tap will not only capture the lead from the segment of LSL where the water stagnated, but it will also collect contributions from the plumbing downstream as the water passes through the remaining LSL and internal plumbing on the way to the kitchen tap. If the sample results only represented the portion of the plumbing where the water stagnated, it would be expected that a variety of metals would be found in the initial liters due to the presence of a variety of metallic plumbing materials and components, but only lead should be found in the LSL samples. In this study, a variety of metals was detected even in samples that represented LSL samples (Figure S6).

Specifically, for Site 9, information provided by the resident indicated that the internal pipe from the LSL to the kitchen tap was galvanized iron pipe. This was confirmed by the co-occurrence of higher levels of zinc and iron within the first liter of water in figure S6. There were no copper pipes in the home, so the presence of the copper is indicative of brass components (faucet, connectors, shut-off valve(s), and the water meter). Trace amounts of iron, zinc and copper are captured in the later liter samples as the water flows through the internal plumbing en route to the kitchen tap, along with traces of iron, potentially from the water main. It can reasonably be

assumed that the same phenomenon occurred for lead. Disturbed areas of the LSL have damaged scale, which can expose water passing through them to fresh lead. Therefore, lead measured in any sample upstream of the damaged area may include lead contributions from the damaged area.

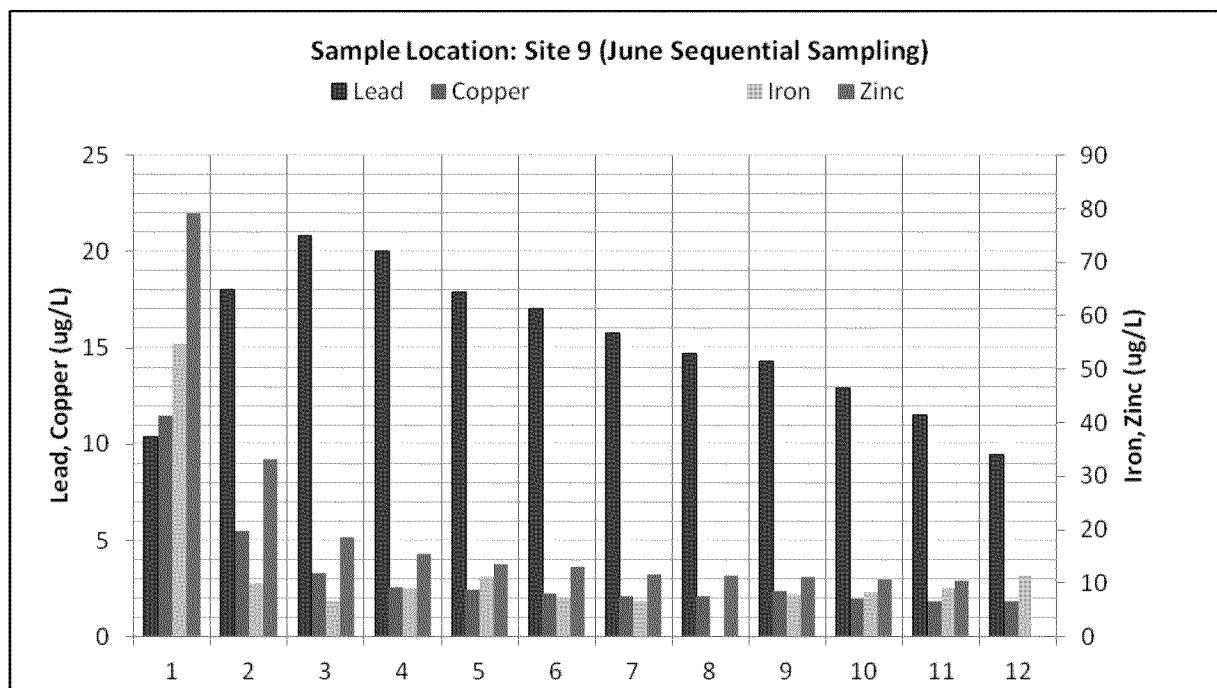


Figure S6: The LSL at Site 9 measures approximately 102 ft (31.1 m) from the water main to the meter. From the meter, there is approximately 13.5 ft (4.1 m) of 1 inch (2.54 cm) galvanized pipe to the kitchen tap.

Variability of lead levels in City B – A second city, City B, exceeded the lead AL during the July-Dec 2010 monitoring period, and was required to comply with the LSL replacement requirements in the LCR. Table S9 contains the compliance monitoring history for City B.

Monitoring Period Begin Date	Monitoring Period End Date	Number of Samples	Lead 90 th Percentile Value (µg/l)
7/1/2011	12/31/2011	101	12
1/1/2011	6/30/2011	130	14
7/1/2010	12/31/2010	105	23
1/1/2009	12/31/2009	51	15
1/1/2008	12/31/2008	58	14
1/1/2007	12/31/2007	50	11
1/1/2006	12/31/2006	60	14
1/1/2005	12/31/2005	54	13
1/1/2004	6/30/2004	104	12
7/1/2003	12/31/2003	108	12
1/1/2002	12/31/2004	50	15
1/1/1999	12/31/1999	55	14
1/1/1998	12/31/1998	50	6
1/1/1997	12/31/1997	50	7
7/1/1996	12/31/1996	50	15
1/1/1996	6/30/1996	50	15
7/1/1992	12/31/1992	50	15
1/1/1992	6/30/1992	50	21

Table S9: City B 90th percentile compliance values (1992 – 2012). Samples that were above the lead AL are in bold.

The sampling instructions presented in Figure S7 are in accordance with the LCR, and were used to collect the LSL samples in City B, which has approximately 25,000 LSLs.

Instructions for Lead Sample Collection	
1	Make sure the faucet used for sample collection is <u>NOT</u> attached to a water softener or any filtering device.
2	At bedtime, make sure the following rule is followed: <ul style="list-style-type: none">○ The water for the entire house, not just the faucet that is being used for collection, remains undisturbed for a period of <u>at least six hours</u>.<ul style="list-style-type: none">▪ No faucets in the house are used, which includes the bath tub, shower and sinks.▪ The toilet is not flushed during this time period.▪ The water is not run for an ice maker.
3	When you are ready to collect the sample: <ul style="list-style-type: none">○ Make sure the sample is taken before any other water is used.<ul style="list-style-type: none">▪ Open the collection container.▪ Turn on the cold water.▪ Allow the water to run until there is a significant change in temperature.▪ Fill the container to the shoulder.▪ Do not rinse the bottle out.▪ <u>Immediately</u> cap the sample container.
4	Fill out the enclosed chain of custody form and survey.
5	Fold and secure the chain of custody form and survey with a rubber band around the outside of the sample container. <ul style="list-style-type: none">○ Place the container outside where it was delivered.
❖	A city utilities employee will pick up the sample container. No one will enter your home. The sample must be left outside to be picked up.

Figure S7: LSL sampling instructions provided by City B to residents.

The sampling protocol used for collecting LSL samples (“allow the water to run until there is a significant change in temperature”) can result in some sample results reflecting lead levels from internal plumbing rather than from within the LSLs.

The results from City B are presented below in Figure S8. Similar to the results presented for the study of Chicago, City B’s results show significant variability in LSL lead levels across the system. Following the 2010 lead AL exceedance, the City B took 1,975 LSL samples, with a total of 1,762 results (89%) below the lead AL and 213 results (11%) above the lead AL. LSL results above the AL were significantly variable, ranging from 16 µg/L to 580 µg/L with a large number of sample results in exceedance of 50 µg/L.

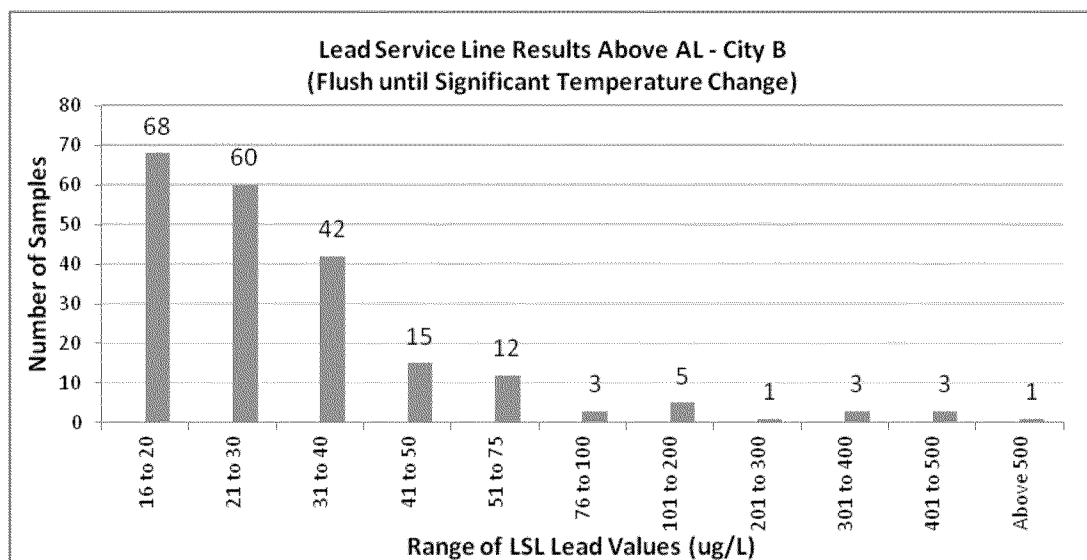
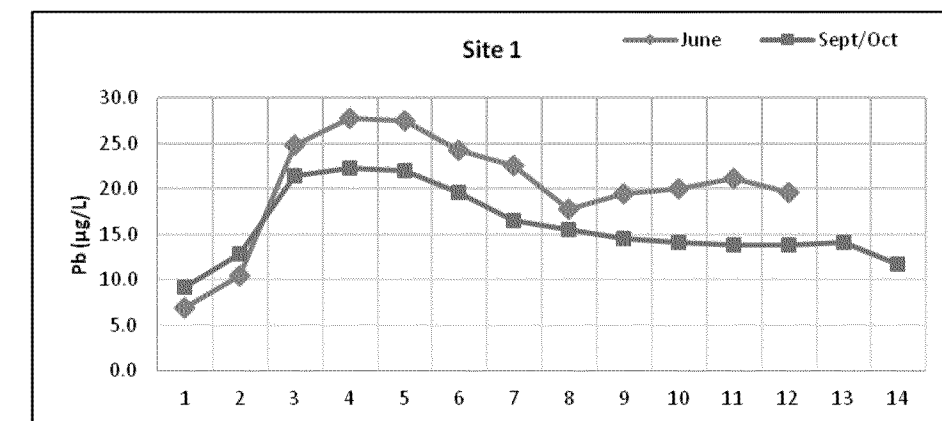


Figure S8: Range of lead values for City B LSL sampling results

Sequential Sampling Summary Graphs –The headers are color-coded based on whether the site has a disturbed LSL (red) or an undisturbed LSL (green). Sites for which this could not be determined (indeterminate sites) are color-coded orange. Water usage information is listed for each site. The samples which contained visible particulates are highlighted yellow, and the results that are above the lead AL are in bold text in the data tables. For sites that conducted sequential sampling in both June and Sept/Oct, the sequential sampling profiles were generally consistent during both sampling periods (see Figures S9 – S40).

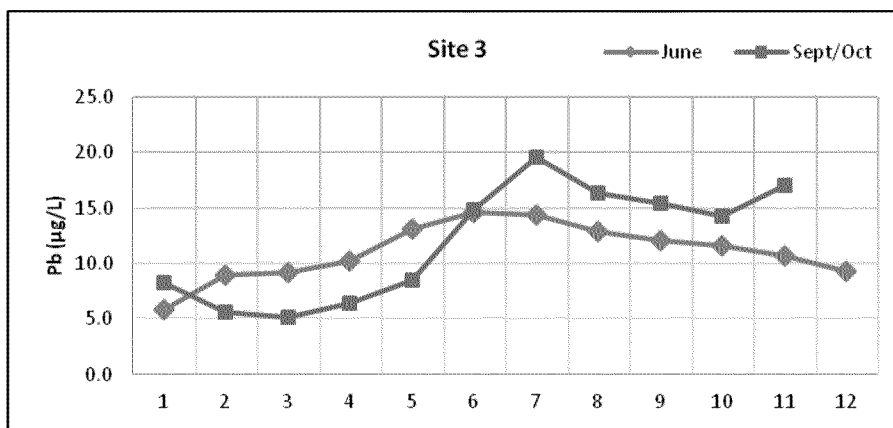
Site 1		
Liter	June	Sept/Oct
1	7.0	9.2
2	11	13
3	25	21
4	28	22
5	28	22
6	24	20
7	23	17
8	18	16
9	20	15
10	20	14
11	21	14
12	20	14
13		14
14		12



Disturbance(s): Water meter installed in 2010
Approximate LSL Length: 89 ft (27.1 m)
Ave Monthly Water Use: 3,444 gal. (13,037 L)

Figure S9: Sequential Lead Results - Sample Site #1 (June and Sept/Oct)

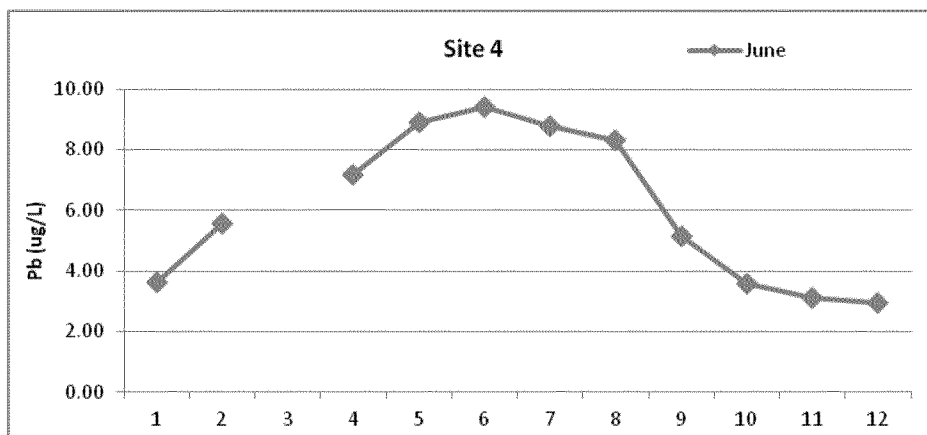
Site 3		
Liter	June	Sept/Oct
1	5.8	8.3
2	8.9	5.6
3	9.2	5.2
4	10	6.4
5	13	8.5
6	15	15
7	14	20
8	13	16
9	12	15
10	12	14
11	11	17
12	9.3	



Disturbance(s): No known disturbance
Approximate LSL Length: 73 ft (22.3 m)
Ave Monthly Water Use: Not metered

Figure S10: Sequential Lead Results - Sample Site #3 (June and Sept/Oct)

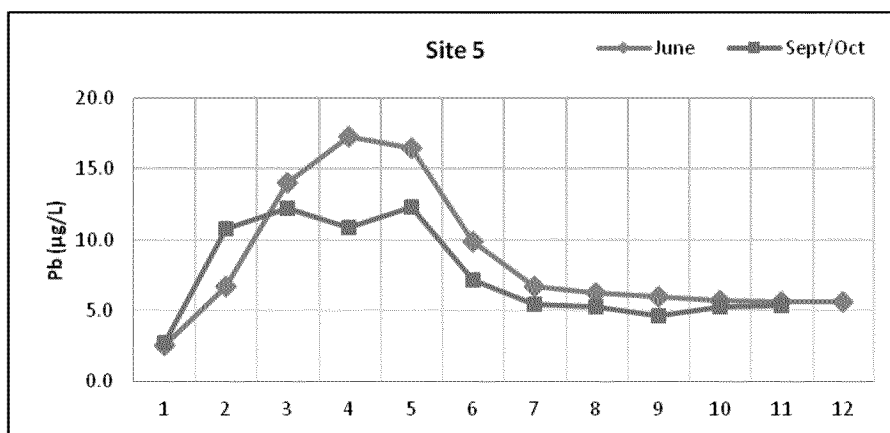
Site 4	
Liter	June
1	3.61
2	5.56
3	
4	7.17
5	8.90
6	9.41
7	8.78
8	8.30
9	5.14
10	3.59
11	3.11
12	2.96



Disturbance(s): No known disturbance
Approximate LSL Length: Unknown
Ave Monthly Water Use: Not metered

Figure S11: Sequential Lead Results - Sample Site #4 (June)

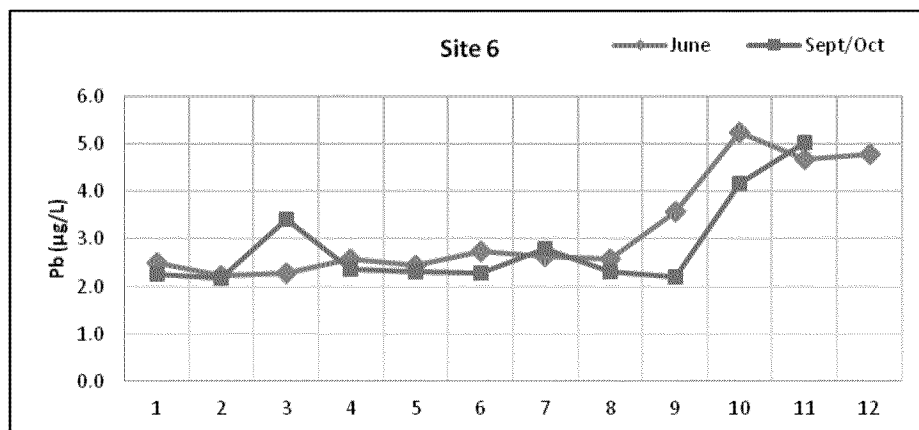
Site 5		
Liter	June	Sept/Oct
1	2.6	2.8
2	6.7	11
3	14	12
4	17	11
5	17	12
6	9.9	7.2
7	6.7	5.5
8	6.3	5.2
9	6.0	4.7
10	5.7	5.3
11	5.7	5.4
12	5.6	



Disturbance(s): Water meter installed in 2011
Approximate LSL Length: 80 ft (24.4 m)
Ave Monthly Water Use: 10,400 gal. (39,368 L)

Figure S12: Sequential Lead Results - Sample Site #5 (June and Sept/Oct)

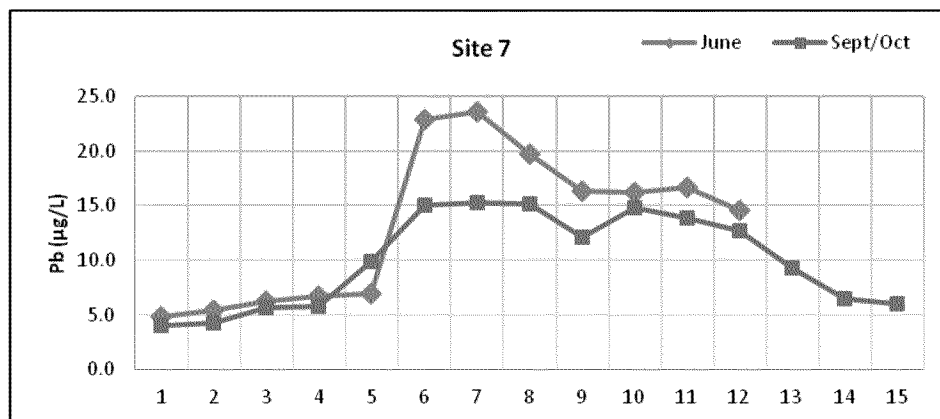
Site 6		
Liter	June	Sept/Oct
1	2.5	2.3
2	2.2	2.2
3	2.3	3.4
4	2.6	2.4
5	2.4	2.3
6	2.8	2.3
7	2.7	2.8
8	2.6	2.3
9	3.6	2.2
10	5.3	4.2
11	4.7	5.0
12	4.8	



Disturbance(s): No known disturbance
Approximate LSL Length: 60 ft (18.3 m)
Ave Monthly Water Use: Not metered

Figure S13: Sequential Lead Results - Sample Site #6 (June and Sept/Oct)

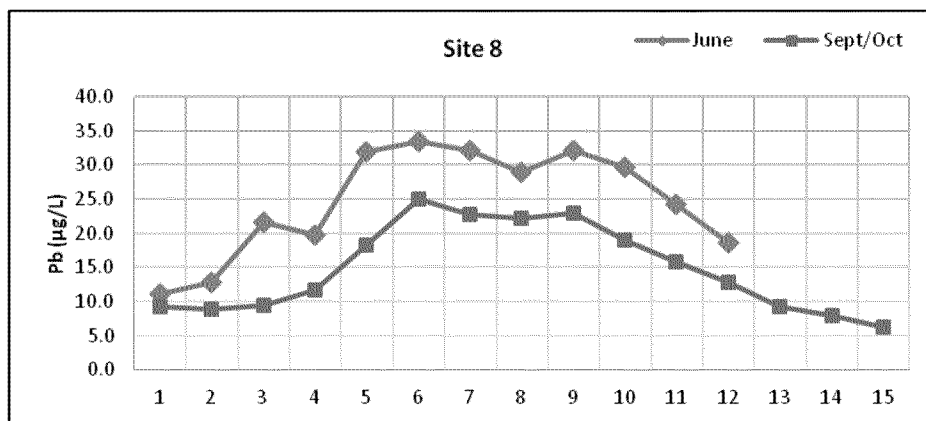
Site 7		
Liter	June	Sept/Oct
1	4.9	4.0
2	5.5	4.3
3	6.3	5.7
4	6.7	5.8
5	7.0	9.9
6	23	15
7	24	15
8	20	15
9	16	12
10	16	15
11	17	14
12	15	13
13		9.3
14		6.5
15		6.0



Disturbance(s): Street excavation, potential installation of Cu whip at service connection in 2008
Approximate LSL Length: 59+ ft (18.0+ m)
Ave Monthly Water Use: Not metered

Figure S14: Sequential Lead Results - Sample Site #7 (June and Sept/Oct)

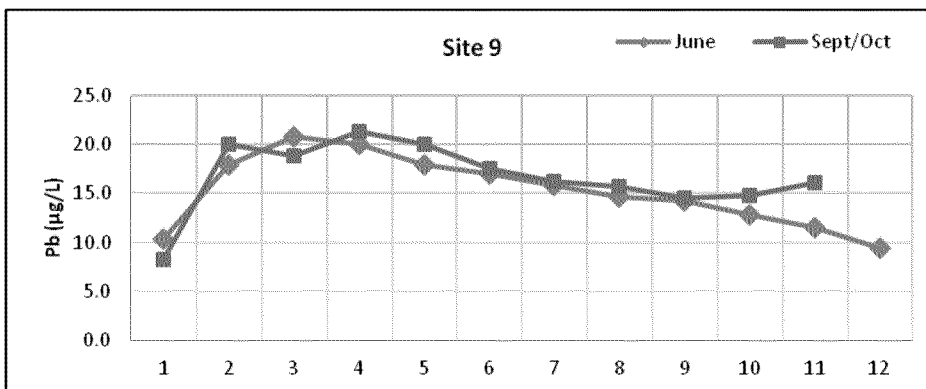
Site 8		
Liter	June	Sept/Oct
1	11	9.2
2	13	9.0
3	22	10
4	20	12
5	32	18
6	34	25
7	32	23
8	29	22
9	32	23
10	30	19
11	24	16
12	19	13
13		9.3
14		7.9
15		6.3



Disturbance(s): Leak in parkway, repaired roundway in 2005.
Approximate LSL Length: 57 ft (17.4 m)
Ave Monthly Water Use: Not metered

Figure S15: Sequential Lead Results - Sample Site #8 (June and Sept/Oct)

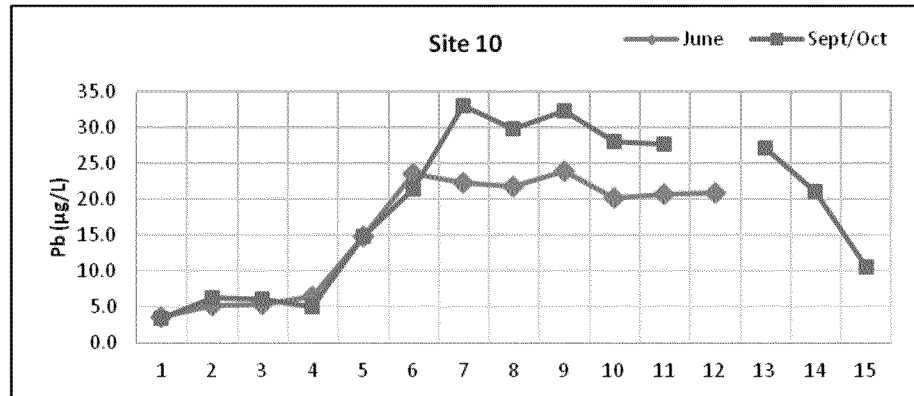
Site 9		
Liter	June	Sept/Oct
1	10	8.3
2	18	20
3	21	19
4	20	21
5	18	20
6	17	18
7	16	16
8	15	16
9	14	15
10	13	15
11	12	16
12	10	



Disturbance(s): Water meter installed in 2008.
Approximate LSL Length: 102 ft (31.1 m)
Ave Monthly Water Use: 3,190 (12,075 L) – In Sept 2011, usage was 24,000 gal. (90,850 L) due to hose left running for one or more days. In calculating the overall average, the Sept 2010 value of 8,000 gal. (30,283 L) was also used for Sept 2011 instead of the 24,000 gal. (90,850 L) value.

Figure S16: Sequential Lead Results - Sample Site #9 (June and Sept/Oct)

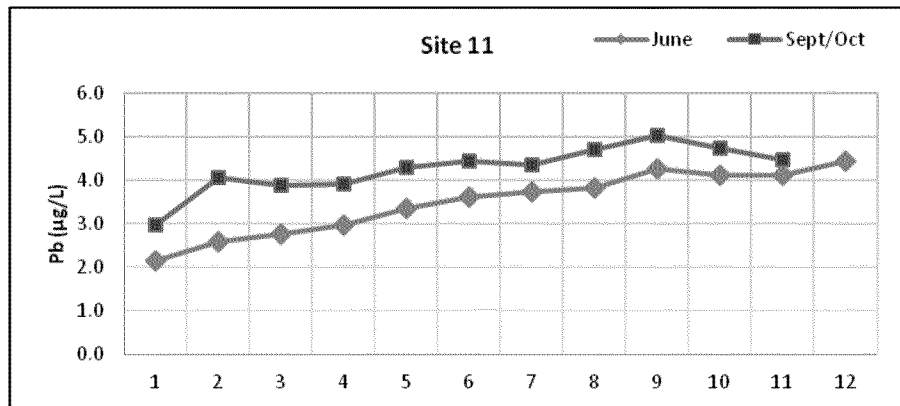
Site 10		
Liter	June	Sept/Oct
1	3.7	3.5
2	5.2	6.3
3	5.4	6.2
4	6.5	5.1
5	15	15
6	24	21
7	22	33
8	22	30
9	24	32
10	20	28
11	21	28
12	21	
13		27
14		21
15		11



Disturbance(s): Service leak repair, water meter installed in 2009.
Approximate LSL Length: 48+ ft (14.6 m)
Ave Monthly Water Use: 1,826 gal. (6,912 L)

Figure S17: Sequential Lead Results - Sample Site #10 (June and Sept/Oct)

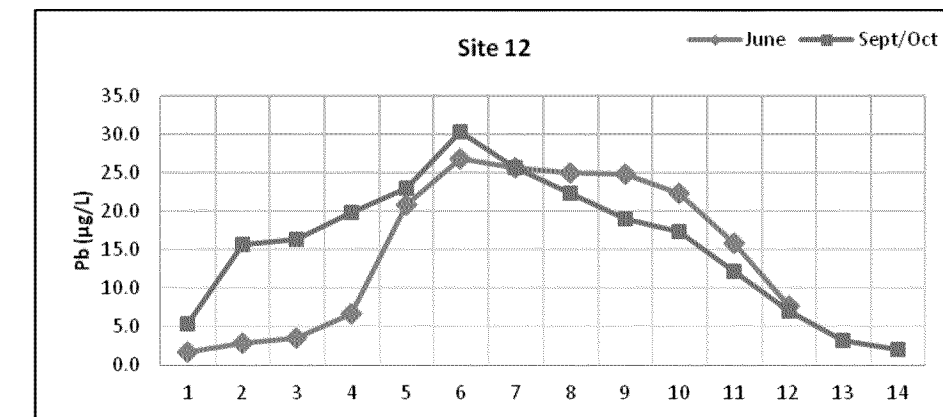
Site 11		
Liter	June	Sept/Oct
1	2.2	3.0
2	2.6	4.1
3	2.8	3.9
4	3.0	3.9
5	3.4	4.3
6	3.6	4.4
7	3.7	4.4
8	3.8	4.7
9	4.3	5.0
10	4.1	4.8
11	4.1	4.5
12	4.4	



Disturbance(s): No known disturbance
Approximate LSL Length: 50 ft (15.2 m)
Ave Monthly Water Use: Not metered

Figure S18: Sequential Lead Results - Sample Site #11 (June and Sept/Oct)

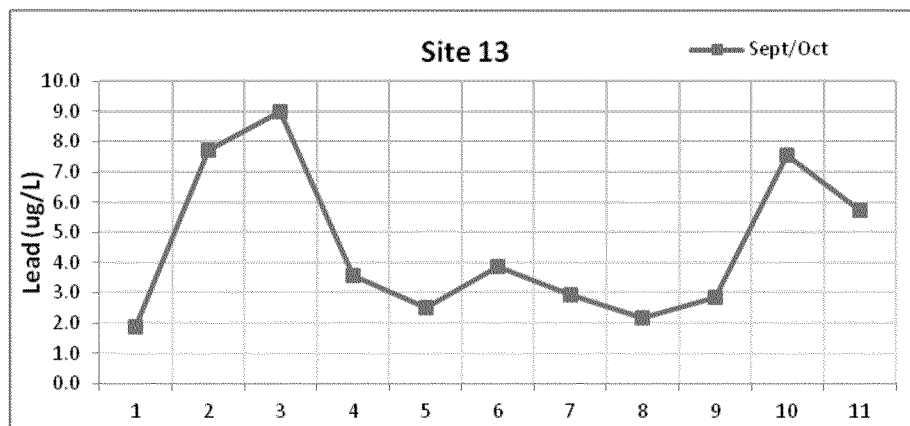
Site 12		
Liter	June	Sept/Oct
1	1.8	5.4
2	3.0	16
3	3.6	16
4	6.7	20
5	21	23
6	27	30
7	26	26
8	25	22
9	25	19
10	22	17
11	16	12
12	7.8	7.0
13		3.3
14		2.0



Disturbance(s): Indeterminate
Approximate LSL Length: 53 (16.2 m)
Ave Monthly Water Use: Not metered

Figure S19: Sequential Lead Results - Sample Site #12 (June and Sept/Oct)

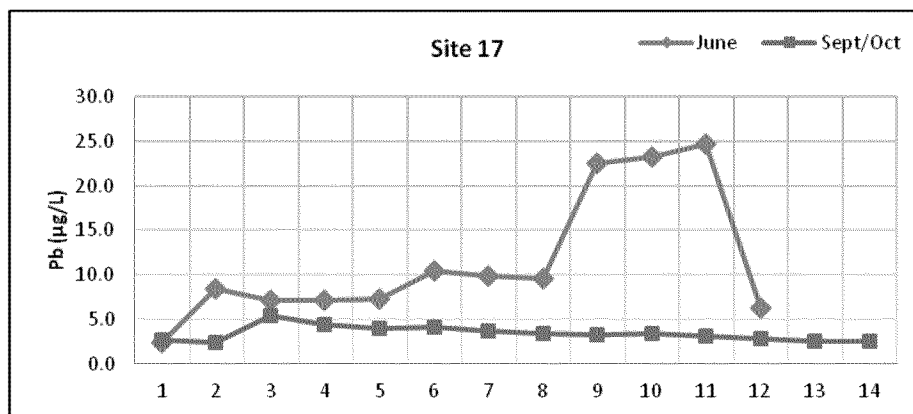
Site 13	
Liter	Sept/Oct
1	1.9
2	7.7
3	9.0
4	3.6
5	2.5
6	3.9
7	3.0
8	2.2
9	2.9
10	7.6
11	5.7



Disturbance(s): No known disturbance
Approximate LSL Length: 49+ ft (4.9 m)
Ave Monthly Water Use: Not metered

Figure S20: Sequential Lead Results - Sample Site #13 (Sept/Oct)

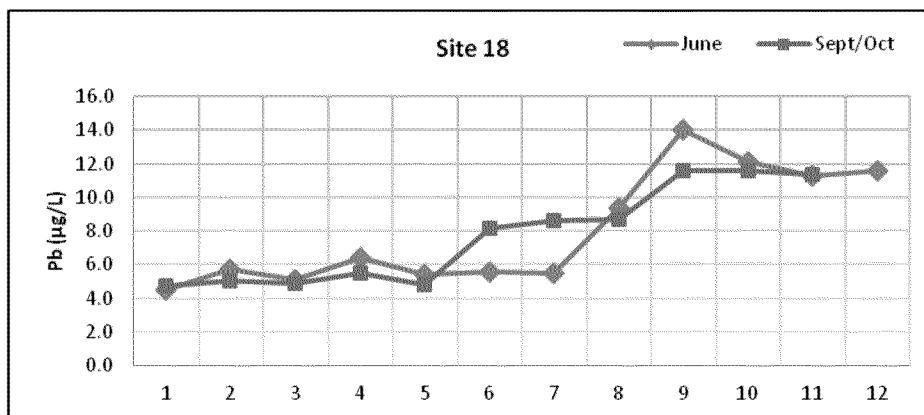
Site 17		
Liter	June	Sept/Oct
1	2.4	2.7
2	8.5	2.4
3	7.1	5.5
4	7.2	4.4
5	7.3	4.1
6	11	4.1
7	9.9	3.7
8	9.6	3.4
9	23	3.4
10	23	3.4
11	25	3.2
12	6.3	2.8
13		2.6
14		2.6



Disturbance(s): Meter replacement in 2008.
 Approximate LSL Length: 58+ ft (17.7+ m)
 Ave Monthly Water Use: 9,772 gal. (36,991 m)

Figure S21: Sequential Lead Results - Sample Site #17 (June and Sept/Oct)

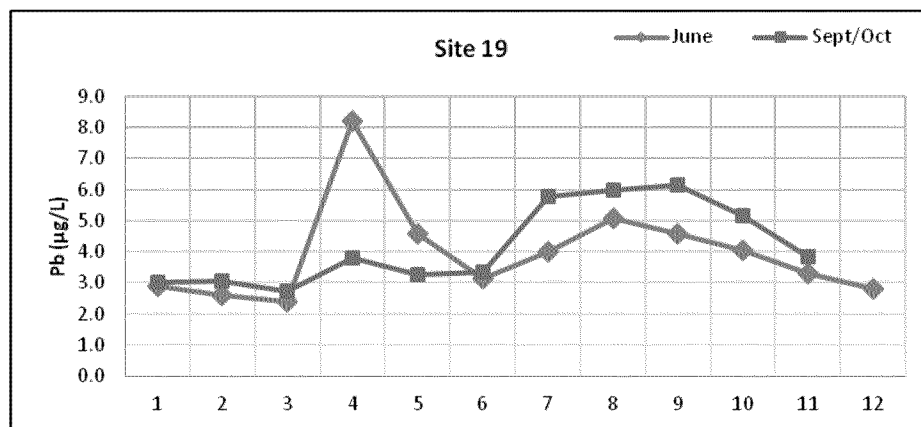
Site 18		
Liter	June	Sept/Oct
1	4.6	4.8
2	5.7	5.1
3	5.1	4.9
4	6.4	5.5
5	5.4	4.8
6	5.6	8.2
7	5.5	8.6
8	9.4	8.7
9	14	12
10	12	12
11	11	11
12	12	



Disturbance(s): No known disturbance
 Approximate LSL Length: 76 ft (23.2 m)
 Ave Monthly Water Use: Not metered

Figure S22: Sequential Lead Results - Sample Site #18 (June and Sept/Oct)

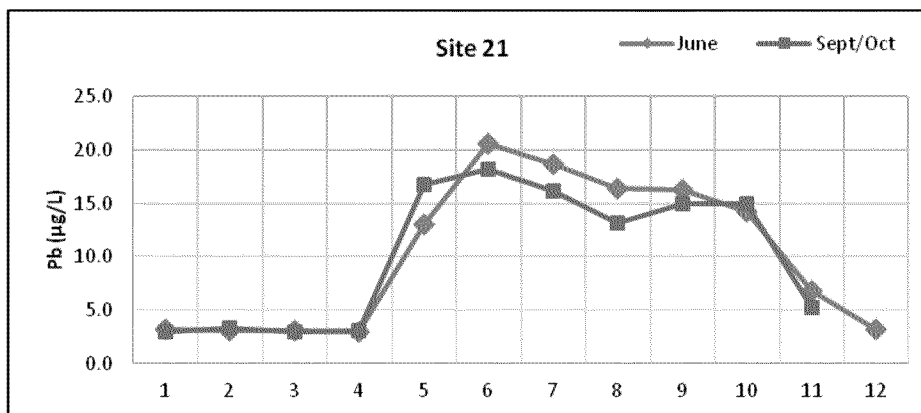
Site 19		
Liter	June	Sept/Oct
1	2.9	3.0
2	2.6	3.1
3	2.4	2.8
4	8.2	3.8
5	4.6	3.3
6	3.2	3.4
7	4.0	5.8
8	5.1	6.0
9	4.6	6.2
10	4.1	5.2
11	3.3	3.8
12	2.8	



Disturbance(s): No known disturbance
Approximate LSL Length: 63 ft (19.2 m)
Ave Monthly Water Use: Not metered

Figure S23: Sequential Lead Results - Sample Site #19 (June and Sept/Oct)

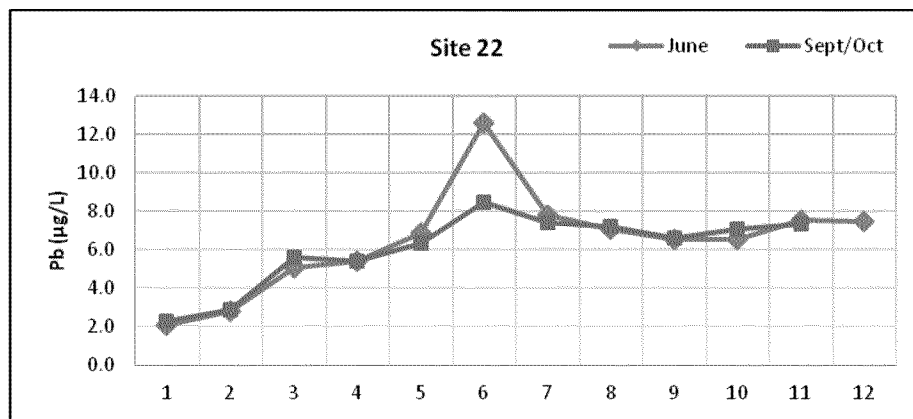
Site 21		
Liter	June	Sept/Oct
1	3.2	3.0
2	3.1	3.4
3	3.1	3.0
4	3.0	3.0
5	13	17
6	21	18
7	19	16
8	16	13
9	16	15
10	14	15
11	7.0	5.2
12	3.2	



Disturbance(s): Indeterminate
Approximate LSL Length: 46 ft (14.0 m)
Ave Monthly Water Use: Not metered

Figure S24: Sequential Lead Results - Sample Site #21 (June and Sept/Oct)

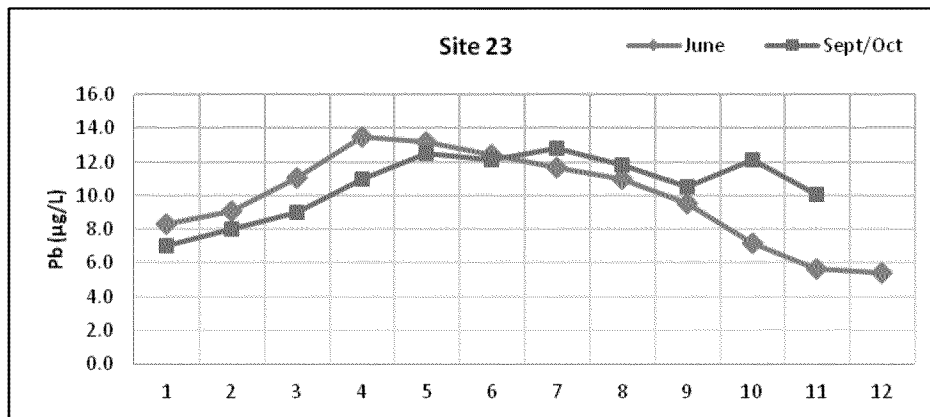
Site 22		
Liter	June	Sept/Oct
1	2.1	2.3
2	2.8	2.9
3	5.1	5.6
4	5.4	5.4
5	6.9	6.3
6	13	8.5
7	7.8	7.4
8	7.1	7.2
9	6.5	6.6
10	6.6	7.1
11	7.6	7.4
12	7.5	



Disturbance(s): No known disturbance
Approximate LSL Length: 65 ft (19.8 m)
Ave Monthly Water Use: Not metered

Figure S25: Sequential Lead Results - Sample Site #22 (June and Sept/Oct)

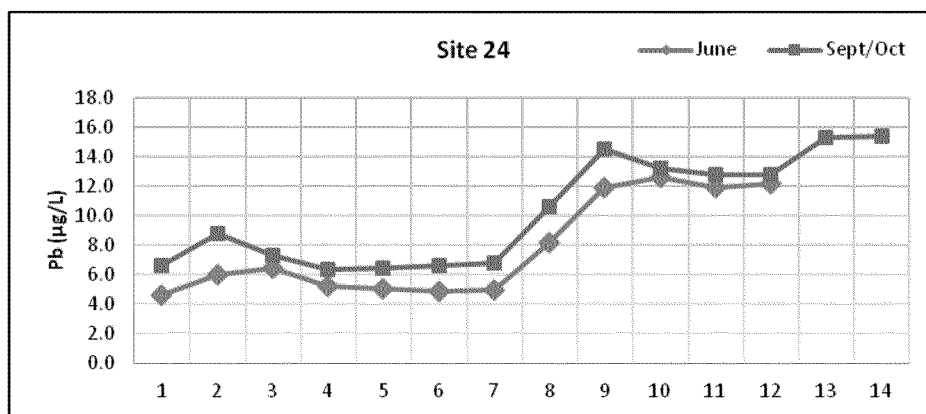
Site 23		
Liter	June	Sept/Oct
1	8.3	7.0
2	9.1	8.0
3	11	9.0
4	14	11
5	13	13
6	12	12
7	12	13
8	11	12
9	9.6	11
10	7.2	12
11	5.7	10
12	5.4	



Disturbance(s): No known disturbance
Approximate LSL Length: 66 ft (20.1 m)
Ave Monthly Water Use: Not metered

Figure S26: Sequential Lead Results - Sample Site #23 (June and Sept/Oct)

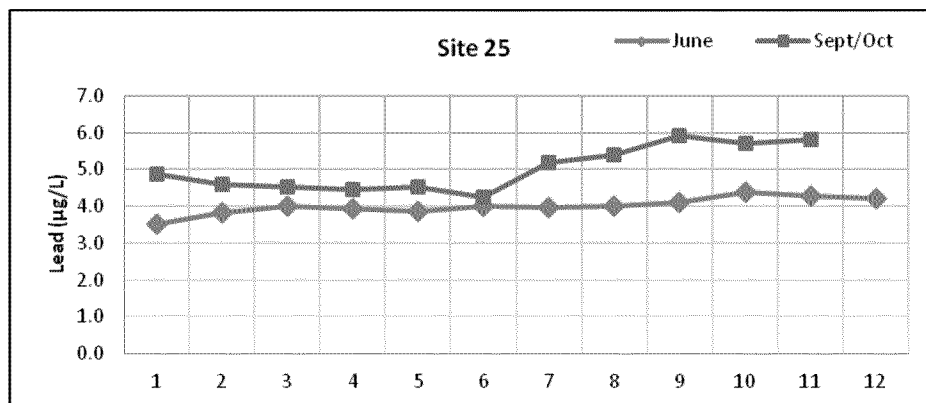
Site 24		
Liter	June	Sept/Oct
1	4.6	6.6
2	6.1	8.8
3	6.4	7.3
4	5.2	6.4
5	5.1	6.5
6	4.9	6.6
7	5.0	6.8
8	8.2	11
9	12	15
10	13	13
11	12	13
12	12	13
13		15
14		15



Disturbance(s): No known disturbance
Approximate LSL Length: 56 ft (17.1 m)
Ave Monthly Water Use: Not metered

Figure S27: Sequential Lead Results - Sample Site #24 (June and Sept/Oct)

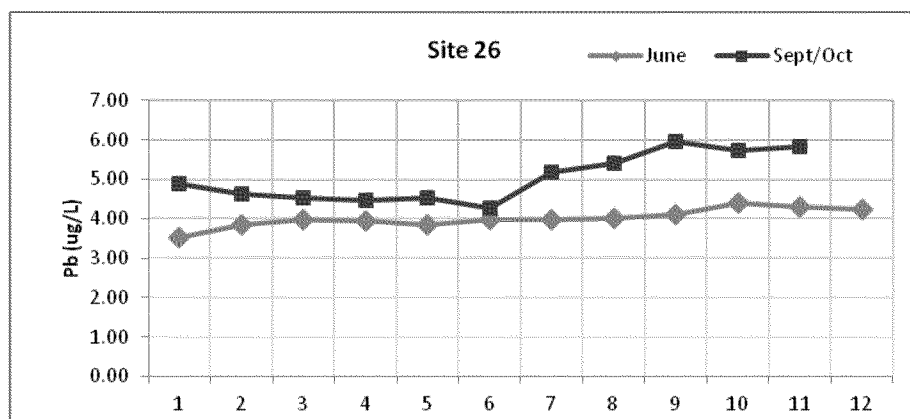
Site 25		
Liter	June	Sept/Oct
1	3.5	4.9
2	3.8	4.6
3	4.0	4.5
4	3.9	4.5
5	3.9	4.5
6	4.0	4.3
7	4.0	5.2
8	4.0	5.4
9	4.1	5.9
10	4.4	5.7
11	4.3	5.8
12	4.2	



Disturbance(s): No known disturbance
Approximate LSL Length: 70 ft (21.3 m)
Ave Monthly Water Use: Not metered

Figure S28: Sequential Lead Results - Sample Site #25 (June and Sept/Oct)

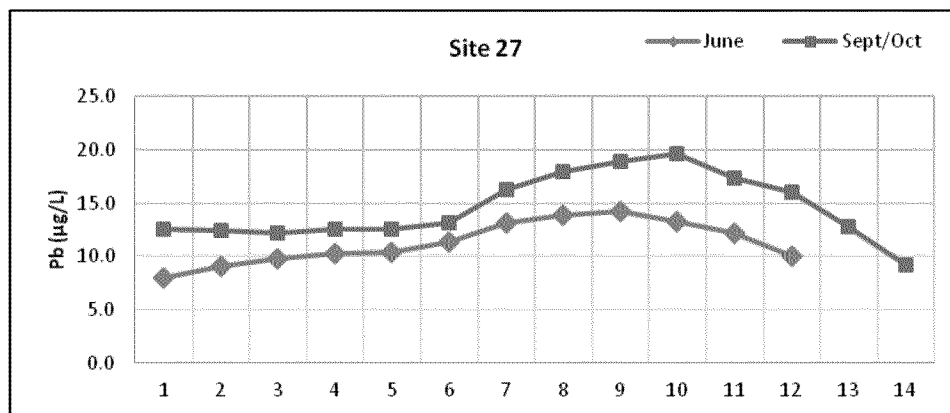
Site 26		
Liter	June	Sept/Oct
1	3.5	4.9
2	3.8	4.6
3	4.0	4.5
4	3.9	4.5
5	3.9	4.5
6	4.0	4.3
7	4.0	5.2
8	4.0	5.4
9	4.1	5.9
10	4.4	5.7
11	4.3	5.8
12	4.2	



Disturbance(s): No known disturbance
Approximate LSL Length: 66 ft (20.1 m)
Ave Monthly Water Use: Not metered

Figure S29: Sequential Lead Results - Sample Site #26 (June and Sept/Oct)

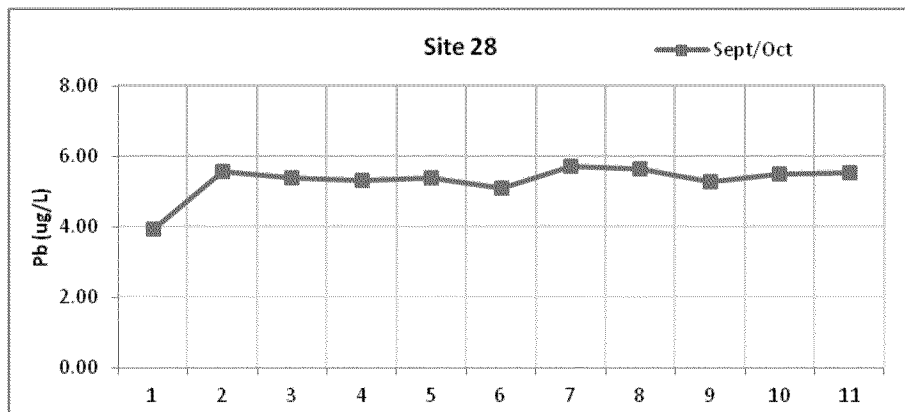
Site 27		
Liter	June	Sept/Oct
1	8.1	13
2	9.1	12
3	9.8	12
4	10	13
5	10	13
6	11	13
7	13	16
8	14	18
9	14	19
10	13	20
11	12	17
12	10	16
13		13
14		9.2



Disturbance(s): Meter replacement in 2010.
Approximate LSL Length: 47+ ft (14.3 m)
Ave Monthly Water Use: 4267 gal. (16,152 L)

Figure S30: Sequential Lead Results - Sample Site #27 (June and Sept/Oct)

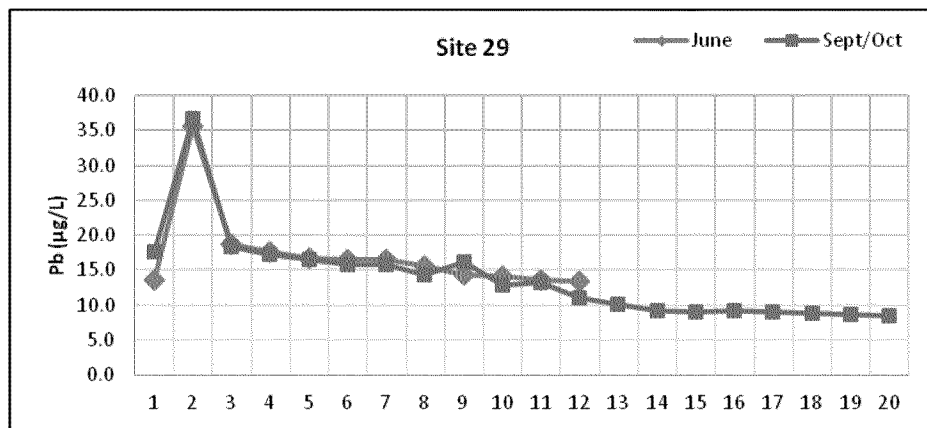
Site 28	
Liter	Sept/Oct
1	3.9
2	5.6
3	5.4
4	5.3
5	5.4
6	5.1
7	5.7
8	5.7
9	5.3
10	5.5
11	5.6



Disturbance(s): Meter replacement in 2009.
 Approximate LSL Length: 61+ ft (18.6+ m)
 Ave Monthly Water Use: 4273 gal. (16,175 L)

Figure S31: Sequential Lead Results - Sample Site #28 (Sept/Oct)

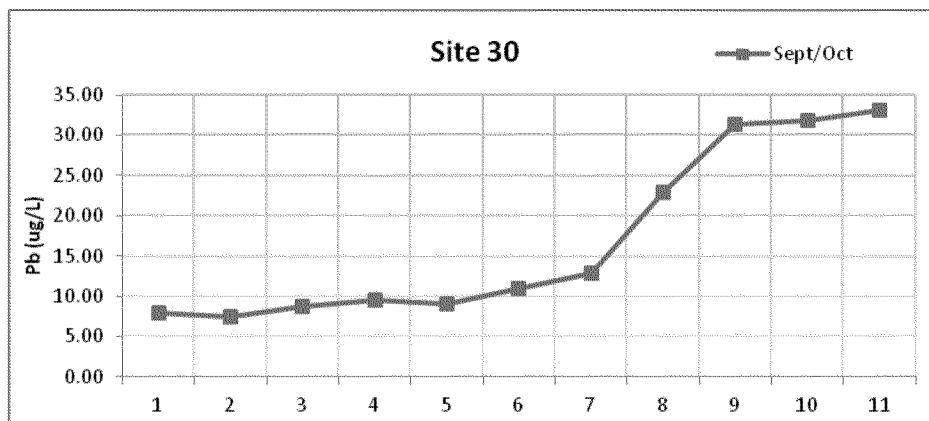
Site 29		
Liter	June	Sept/Oct
1	14	18
2	36	37
3	19	18
4	18	17
5	17	17
6	17	16
7	17	16
8	16	14
9	14	16
10	14	13
11	14	13
12	13	11
13		10
14		9.2
15		9.0
16		9.3
17		9.0
18		8.8
19		8.7
20		8.4



Disturbance(s): Probable Approximate LSL leak repair, meter installed in 2010.
 Approximate LSL Length: 159 ft (48.5 m)
 Ave Monthly Water Use: 1,438 gal. (5,443 L)

Figure S32: Sequential Lead Results - Sample Site #29 (June and Sept/Oct)

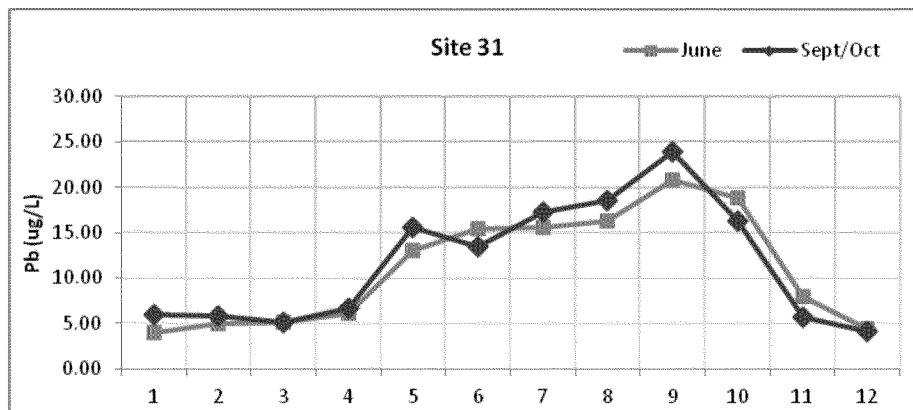
Site 30	
Liter	Sept/Oct
1	7.9
2	7.5
3	8.7
4	9.5
5	9.1
6	11
7	13
8	23
9	31
10	32
11	33



Disturbance(s): Broken water main in 2000, sidewalk replaced & street re-surfacing.
 Approximate LSL Length: 49+ ft (14.9 m)
 Ave Monthly Water Use: Not metered

Figure S33: Sequential Lead Results - Sample Site #30 (Sept/Oct)

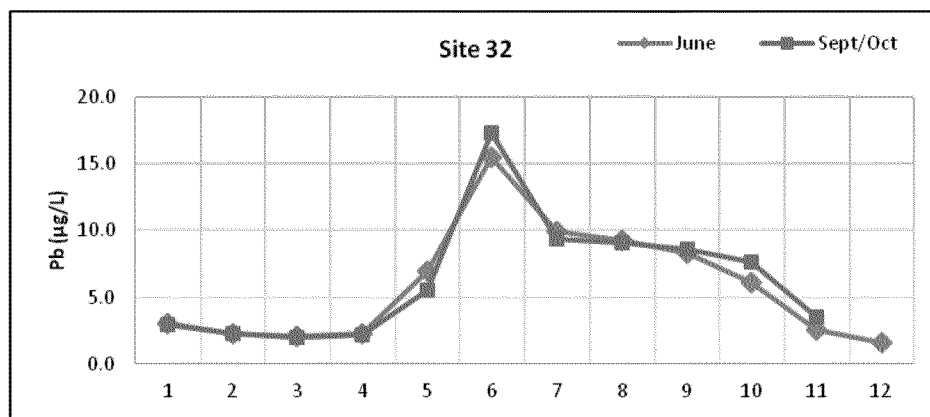
Site 31		
Liter	June	Sept/Oct
1	4.0	6.0
2	5.0	5.8
3	5.1	5.2
4	6.2	6.7
5	13	16
6	15	13
7	16	17
8	16	19
9	21	24
10	19	16
11	8	5.7
12	4.5	4.2



Disturbance(s): Approximate LSL leak repair in 2010.
 Approximate LSL Length: 71+ ft (21.6+ m)
 Ave Monthly Water Use: Not metered

Figure S34: Sequential Lead Results - Sample Site #31 (June and Sept/Oct)

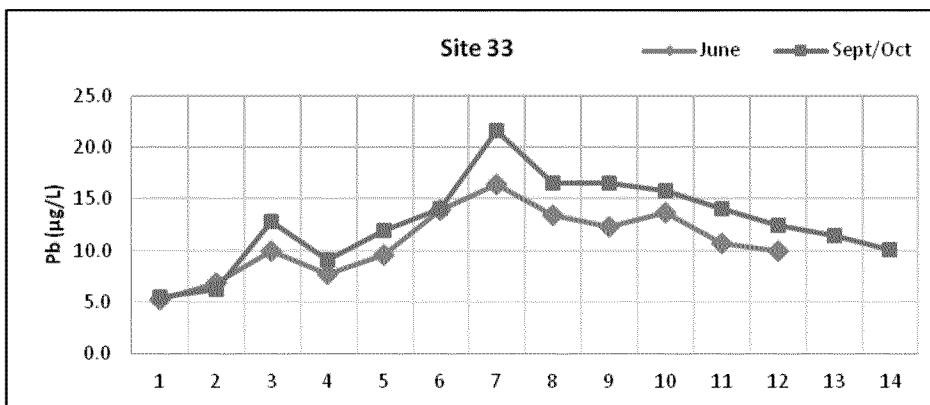
Site 32		
Liter	June	Sept/Oct
1	3.1	2.9
2	2.3	2.2
3	2.1	2.0
4	2.3	2.2
5	7.0	5.5
6	16	17
7	9.9	9.4
8	9.3	9.1
9	8.3	8.6
10	6.1	7.6
11	2.6	3.5
12	1.7	



Disturbance(s): No known disturbance
Approximate LSL Length: 43 ft (13.1 m)
Ave Monthly Water Use: Not metered

Figure S35: Sequential Lead Results - Sample Site #32 (June and Sept/Oct)

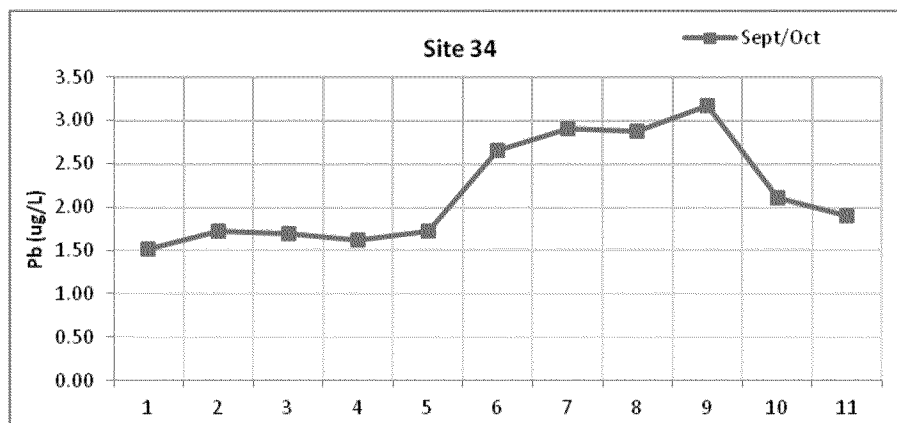
Site 33		
Liter	June	Sept/Oct
1	5.2	5.5
2	6.9	6.3
3	10	13
4	7.7	9.1
5	9.6	12
6	14	14
7	16	22
8	14	17
9	12	17
10	14	16
11	11	14
12	10	12
11		12
12		10



Disturbance(s): Indeterminate
Approximate LSL Length: 43+ ft (13.1 m)
Ave Monthly Water Use: Not metered

Figure S36: Sequential Lead Results - Sample Site #33 (June and Sept/Oct)

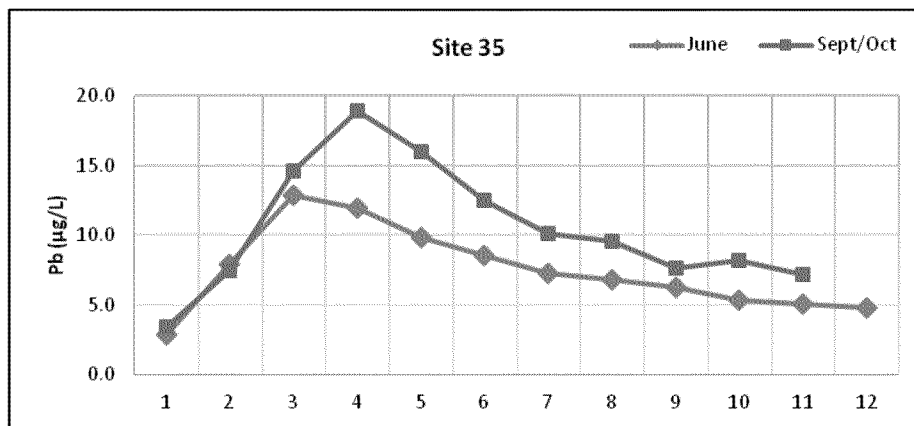
Site 34	
Liter	Sept/Oct
1	1.5
2	1.7
3	1.7
4	1.6
5	1.7
6	2.7
7	2.9
8	2.9
9	3.2
10	2.1
11	1.9



Disturbance(s): No known disturbance
Approximate LSL Length: Unknown
Ave Monthly Water Use: Not metered

Figure S37: Sequential Lead Results - Sample Site #34 (Sept/Oct)

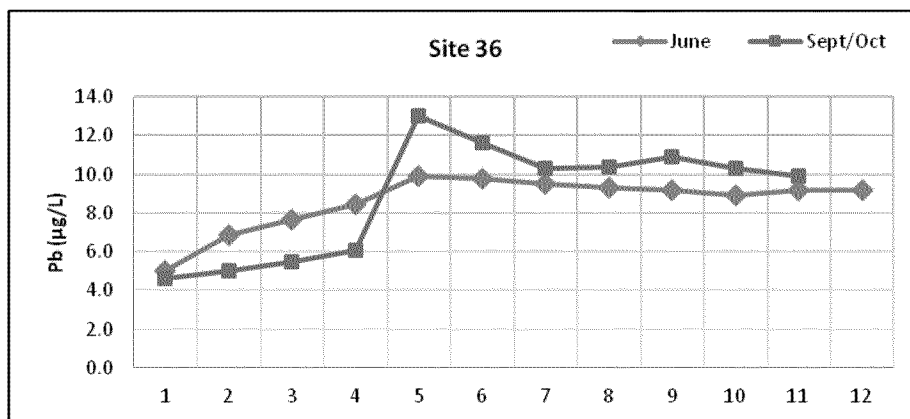
Site 35		
Liter	June	Sept/Oct
1	2.9	3.4
2	7.9	7.4
3	13	15
4	12	19
5	9.9	16
6	8.6	13
7	7.3	10
8	6.8	9.6
9	6.2	7.6
10	5.3	8.2
11	5.0	7.2
12	4.8	



Disturbance(s): Meter installed in Aug 2011 (between June and Sept/Oct sampling).
Approximate LSL Length: 80 ft (24.4 m)
Ave Monthly Water Use: 4,667 gal. (17,667 L) – Data available only for Aug-Oct 2011

Figure S38: Sequential Lead Results - Sample Site #35 (June and Sept/Oct)

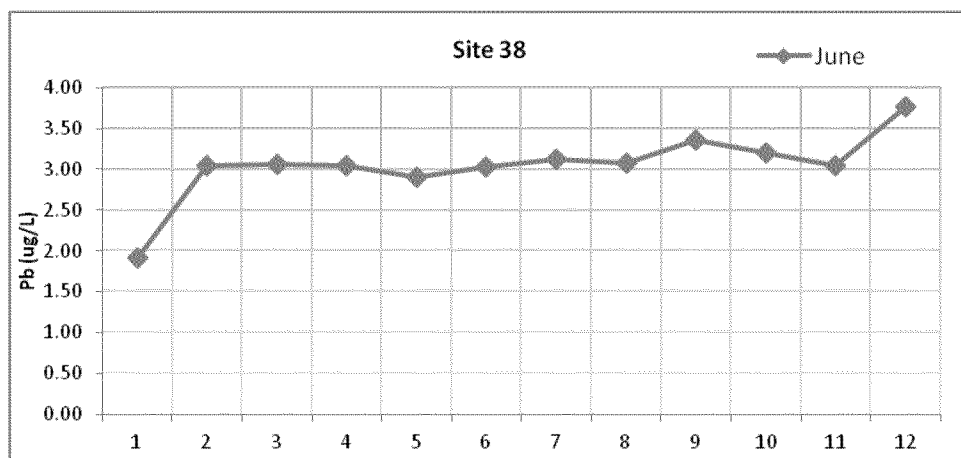
Site 36		
Liter	June	Sept/Oct
1	5.0	4.6
2	6.9	5.0
3	7.7	5.5
4	8.5	6.1
5	9.9	13
6	9.8	12
7	9.5	10
8	9.3	10
9	9.2	11
10	8.9	10
11	9.2	9.9
12	9.2	



Disturbance(s): No known disturbance
Approximate LSL Length: 83+ ft (25.3 m)
Ave Monthly Water Use: Not metered

Figure S39: Sequential Lead Results - Sample Site #36 (June and Sept/Oct)

Site 38	
Liter	June
1	1.9
2	3.0
3	3.1
4	3.0
5	2.9
6	3.0
7	3.1
8	3.1
9	3.4
10	3.2
11	3.0
12	3.8



Disturbance(s): No known disturbance
Approximate LSL Length: 51 ft (15.5 m)
Ave Monthly Water Use: Not metered

Figure S40: Sequential Lead Results - Sample Site #38 (June)

Sampling collection and reporting instructions and forms

March/April sampling – The sampling instructions and forms below were used in the March/April sampling. Sampling was scheduled to conclude in March, but the sampling ran into April. As a result of the instructions below, some volunteers sampled one day at the kitchen tap and one day at the bathroom tap. The intent was to have all samples collected from the same tap, so volunteers that split the samples were asked to collect replacement samples so that a complete set of four samples was collected at the same tap. We chose the kitchen tap, and all samples collected thereafter were also collected at the kitchen tap. In addition, the 45-second flushed

sampling protocol was not used after the March/April sampling due to the complication with corroded galvanized pipe.

General Sampling Instructions

You will be taking a total of 8 samples for this study. One set of 4 samples will be taken in March 2011 and one set of 4 samples (using the same instructions) will be taken in August 2011.

General Instructions for all four samples of a set

Sample #1 and Sample #2 must be collected one after another on the same day.

Sample #3 and Sample #4 must also be collected one after another on the same day, and within the same week as Sample #1 and Sample #2.

All samples should be collected from taps that are generally used by your household for drinking water. **Do not** collect samples from a taps that have not been used within the last 24 hours. Use a kitchen or bathroom cold-water faucet for your sampling.

Do not collect samples from a tap that has a water filter or is connected to a water softener. If you have a water softener or water filter on your kitchen tap, collect your sample from a bathroom tap that is not attached to the water softener or water filter, if possible.

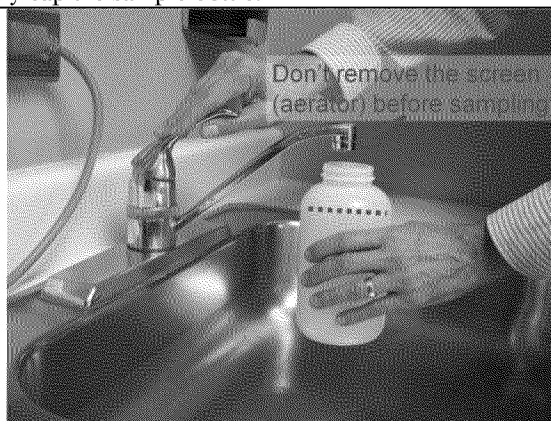
Instructions for Collecting Sample #1

Important: Please make sure you use the bottle labeled 'Sample #1' for your first sample!

Collecting Sample #1: The first sample is to be collected after water throughout the household *has not been used for a minimum of 6 hours* (example: midnight to 6am). During these 6 hours, do not flush toilets, shower, or run water from other faucets. The best time to collect samples is either:

1) First thing in the morning, before any water is used in the household; or 2) Immediately upon returning from work, and prior to using any water, as long as water has not been used in the household during the day.

1. When you are ready to collect your first sample, use the sample bottle labeled 'Sample #1'.
2. Do not run any water from the tap before collecting the first sample.
3. Place the opened sample bottle below the faucet and gently open the cold water tap.
4. Fill the sample bottle as you would normally fill a glass of water for drinking, up to the neck of the bottle (see photographs below) and turn off the water. Tightly cap the sample bottle.



Instructions for Collecting Sample #2

Important: Please make sure you use the bottle labeled 'Sample #2' for your second sample!

Collecting Sample #2: This sample is to be collected from the same faucet as Sample #1, immediately after collecting Sample #1.

1. Immediately after collecting Sample #1, run the water for 45 seconds. Shut off the water, and place the opened

<p>sample bottle (labeled Sample #2) below the faucet and gently open the cold water tap.</p> <p>2. Fill the sample bottle as you would normally fill a glass of water for drinking, up to the neck of the bottle (see photographs on first page) and turn off the water. Tightly cap the sample bottle.</p>
<p>Instructions for Collecting Sample #3</p>
<p><u>Important: Please make sure you use the bottle labeled 'Sample #3' for your third sample!</u></p> <p><u>Collecting Sample #3:</u> Collect on a different day in the same week as Samples #1 & #2.</p> <ol style="list-style-type: none"> 1. <i>Before</i> letting the water sit for a minimum of 6 hours, run the water from the faucet for 5 minutes at a high rate, and then do not use any water in the household for at least 6 hours after that (Example: Run the water for 5 minutes at midnight before going to bed, and then do not use any water in the household until collecting the third sample at 6 am the following morning). 2. Do not run any more water from the tap before collecting the third sample. Place the opened sample bottle below the faucet and gently open the cold water tap. 3. Fill the sample bottle as you would normally fill a glass of water for drinking, up to the neck of the bottle (see photographs on first page) and turn off the water. Tightly cap the sample bottle.
<p>Instructions for Collecting Sample #4</p>
<p><u>Important: Please make sure you use the bottle labeled 'Sample #4' for your fourth sample!</u></p> <p><u>Collecting Sample #4:</u> This sample is to be collected from the same faucet as Sample #3.</p> <ol style="list-style-type: none"> 1. Immediately after collecting Sample #3, <u>run the water for 45 seconds</u>. Shut off the water, and place the opened sample bottle (labeled Sample #4) below the faucet and gently open the cold water tap. 2. Fill the sample bottle as you would normally fill a glass of water for drinking, up to the neck of the bottle (see photographs on first page) and turn off the water. Tightly cap the sample bottle.

Figure S41: March/April sampling instructions.

Sample Collection and Reporting Page	
Sample Reporting – Sample #1	EPA Use: Visible Particulate? Yes <input type="checkbox"/> No <input type="checkbox"/>
<p>Sample ID (from Sample Bottle #1): _____ Date/time Sample #1 was collected: _____</p> <p>Volunteer ID: _____ Sampling Location: Kitchen Faucet <input type="checkbox"/> Bathroom Faucet <input type="checkbox"/></p> <p>Date/time the water was last used in household before collecting Sample #1: _____</p> <p>Was sample #1 collected from a faucet that has a water softener or water filter? Yes <input type="checkbox"/> No <input type="checkbox"/></p>	
Sample Reporting – Sample #2	EPA Use: Visible Particulate? Yes <input type="checkbox"/> No <input type="checkbox"/>
<p>Sample ID (from Sample Bottle #2): _____ Date/time Sample #2 was collected: _____</p> <p>Volunteer ID: _____ Sampling Location: Kitchen Faucet <input type="checkbox"/> Bathroom Faucet <input type="checkbox"/></p> <p>Date/time the water was last used in household before collecting Sample #2: _____</p> <p>Was Sample #2 collected from the same faucet as Sample #1: Yes <input type="checkbox"/> No <input type="checkbox"/></p>	
Sample Reporting – Sample #3	EPA Use: Visible Particulate? Yes <input type="checkbox"/> No <input type="checkbox"/>
<p>Sample ID (from Sample Bottle #3): _____ Date/time Sample #3 was collected: _____</p> <p>Volunteer ID: _____ Sampling Location: Kitchen Faucet <input type="checkbox"/> Bathroom Faucet <input type="checkbox"/></p> <p>Date/time the faucet was flushed before collecting Sample #3: _____</p> <p>Was sample #3 collected from a faucet that has a water softener or water filter? Yes <input type="checkbox"/> No <input type="checkbox"/></p>	
Sample Reporting – Sample #4	EPA Use: Visible Particulate? Yes <input type="checkbox"/> No <input type="checkbox"/>
<p>Sample ID (from Sample Bottle #4): _____ Date/time Sample #4 was collected: _____</p> <p>Volunteer ID: _____ Sampling Location: Kitchen Faucet <input type="checkbox"/> Bathroom Faucet <input type="checkbox"/></p> <p>Date/time the faucet was flushed before collecting Sample #4: _____</p> <p>Was Sample #4 collected from the same faucet as Sample #3: Yes <input type="checkbox"/> No <input type="checkbox"/></p> <p>Have there been any plumbing repairs or plumbing work done within the household during the last six months (including installation of new faucets)? Yes <input type="checkbox"/> No <input type="checkbox"/></p> <p>If yes, explain briefly (Example – ‘New faucet installed one week ago’):</p> 	
<p>FOR EPA USE: Samples received by _____ Date/Time: _____</p> <p>Samples transferred to Region 5 Laboratory by _____ Date/Time: _____</p>	

Volunteer Certification: I have read the sampling instructions and have collected the samples in accordance with the instructions provided.

Signature/Date

OR

Volunteer ID/Date

Figure S42: March/April sample collection and reporting form.

Sequential Sampling Instructions for June – The sampling instructions and forms below were used in the June sequential sampling.

Sequential Sampling Instructions	
<p>Please read all instructions before beginning your sampling</p> <p><u>General Information</u></p> <ul style="list-style-type: none"> • Use <u>only the kitchen faucet</u> for all of these samples. • Use only cold water and open the cold water tap all the way when filling the bottles. • Fill each bottle to the top of the label on the sample bottle. <p><u>Sampling Instructions</u></p> <ul style="list-style-type: none"> • The night before sampling (right before everyone goes to bed) run the water from the kitchen tap for at least 5 minutes. Write down the date/time you finished running the water on the form on the back side of this page. • The water must sit motionless in the home plumbing for at least 6 hours before collecting the samples so do not use water in the home after you finished running the water and until all samples are collected the following morning. Showering, flushing toilets, or other water use will affect the sampling results. It may help to tape a sign in the kitchen and bathrooms with a reminder not to use the water, in case people forget. • The bottles are numbered, and <u>it is very important to collect them in order</u> (Sample 1 first, Sample 2 second, etc.). • In the morning, when you are ready to sample, place the open bottles in order by sample number. You will be collecting the samples without shutting off the water in between samples, so you should remove the caps from all bottles so that you have all of the bottles ready to fill. You can put the caps on after all samples have been collected. Try not to let any water spill in between samples. • Write down the date/time right before you sample on the form on the back side of this page. • Begin by placing the Sample 1 bottle under the faucet and open the cold water slowly until the faucet is <u>fully open</u>. While one bottle is filling, grab the next bottle so that you are ready to move it under the faucet quickly. • Once the bottle is filled to the top of the label, quickly place the Sample 2 bottle under the faucet, and continue until you have filled all sample bottles. 	
Sequential Sampling – Sample Collection and Reporting Form	
<p>Volunteer ID: _____</p>	
Sampling Information	
<p>Date/time the water was last used in household (the night before collecting the samples): _____</p> <p>Date/Time Volunteer Began Collecting Samples: _____</p> <p>Were All Samples Collected from the Kitchen Tap? Yes <input type="checkbox"/> No <input type="checkbox"/></p>	
<p>FOR EPA USE: Samples received by _____ Date/Time: _____</p> <p>Samples transferred to Region 5 Laboratory by _____ Date/Time: _____</p> <p>EPA Use: Visible Particulate in any samples? Yes <input type="checkbox"/> No <input type="checkbox"/> If Yes – List Samples With Particulate _____</p>	
<p><i>Volunteer Certification: I have read the sampling instructions and have collected the samples in accordance with the instructions provided.</i></p>	
<p>_____</p> <p><i>Signature/Date</i></p>	<p>OR</p> <p>_____</p> <p><i>Volunteer ID/Date</i></p>

Figure S43: June sampling instructions and sample collection and reporting form.

Sampling instructions for September/October – In the final round of sampling, the number and type of samples was customized to each site and sites collected 3 days of sampling. The instructions below were for a site collecting one NHU First-draw sample, 11 sequential samples and a 2 flushed samples. Some sites collected additional sequential samples and some collected 3 flushed samples instead of two.

Sampling Instructions	
Please read all instructions before you start sampling.	
General Information <ul style="list-style-type: none"> <input type="checkbox"/> Use only the kitchen faucet for all of these samples. <input type="checkbox"/> Use only cold water. <input type="checkbox"/> Open the cold water tap all the way when filling the bottles. <input type="checkbox"/> Fill each bottle to the top of the label on the sample bottle. 	
Sampling Instructions <ul style="list-style-type: none"> <input type="checkbox"/> There are three different sets of samples for you to collect (Sample Set #1, #2 and #3). <input type="checkbox"/> Each set will be taken on a different day. (The three sampling sets do not have to be taken on three days in a row.) <input type="checkbox"/> A section of the reporting form (attached) needs to be filled in for each day of sampling. 	
A) Sample Set #1 (1 bottle, Blue Label) <ol style="list-style-type: none"> 1. The water must sit motionless in the home plumbing for at least 6 hours before collecting the sample. Typically, the night before taking the sample, make sure that no one uses water in the home until you collect the sample from the kitchen the following morning. 2. In the morning, when you are ready to sample, write down the date/time on the attached form. 3. Fill up the bottle with the BLUE LABEL. That's it for collecting the first sample set. 	
B) Sample Set #2 "Sequential Sampling" (11 bottles, WHITE LABELS) <ol style="list-style-type: none"> 1. The night before sampling (right before everyone goes to bed) run the water from the kitchen tap for at least 5 minutes. Write down the date/time you finished running the water on the form. After running the water for 5 minutes, it should sit motionless in the home plumbing for at least 6 hours. 2. In the morning, your first water usage should be collecting eleven samples in a row (one after another). Use the bottles with the WHITE LABELS. The samples should be collected without shutting off the water in between samples. To do this, remove the caps from all eleven bottles before you turn on the water. 3. Place the eleven open bottles in order by sample number before you start collecting the samples Try not to waste water in between the samples. You can put the caps on after all 11 samples have been collected. The bottles are numbered Seq 01, to Seq 11. It is very important to collect the samples in order (Seq 01 first, Seq 02 second, etc.). 4. Use the attached reporting form to note the date and time that you started taking the sample set. 	
C) Sample Set #3 (2 Bottles, GREEN LABEL and YELLOW LABEL) <ol style="list-style-type: none"> 1. The night before sampling (right before everyone goes to bed) run the water from the kitchen tap for at least 5 minutes. Write down the date/time you finished running the water on the form. After running the water for 5 minutes, it should sit motionless in the home plumbing for at least 6 hours. 2. In the morning, when you are ready to sample, write down the date/time on the attached reporting form. 3. Run the water for 3 minutes, then collect a sample in the jar with the GREEN LABEL. Continue to let the water run for an additional 2 minutes (for a total of 5 minutes), and collect the final sample in the bottle with the YELLOW LABEL. 	

Figure S44: Sept/Oct sampling instructions.

Sample Collection and Reporting – Sampling set # 1 (Blue label)	
Volunteer ID: _____	
Sampling Information	
Date/time the water was last used in household (the night before collecting the samples): _____	
Date/Time Volunteer Began Collecting Samples: _____	
Were All Samples Collected from the Kitchen Tap? Yes <input type="checkbox"/> No <input type="checkbox"/>	
FOR EPA USE: Samples received by _____ Date/Time: _____	
Samples transferred to Region 5 Laboratory by _____ Date/Time: _____	
EPA Use: Visible Particulate in any samples? Yes <input type="checkbox"/> No <input type="checkbox"/> If Yes – List Samples With Particulate _____	
Sample Collection and Reporting - Sampling set # 2 (11 samples, White labels)	
Volunteer ID: _____	
Sampling Information	
Date/time the water was last used in household (the night before collecting the samples): _____	
Date/Time Volunteer Began Collecting Samples: _____	
Were All Samples Collected from the Kitchen Tap? Yes <input type="checkbox"/> No <input type="checkbox"/>	
FOR EPA USE: Samples received by _____ Date/Time: _____	
Samples transferred to Region 5 Laboratory by _____ Date/Time: _____	
EPA Use: Visible Particulate in any samples? Yes <input type="checkbox"/> No <input type="checkbox"/> If Yes – List Samples With Particulate _____	
Sample Collection and Reporting - Sampling set # 3 (Green and Yellow labels)	
Volunteer ID: _____	
Sampling Information	
Date/time the water was last used in household (the night before collecting the samples): _____	
Date/Time Volunteer Began Collecting Samples: _____	
Were All Samples Collected from the Kitchen Tap? Yes <input type="checkbox"/> No <input type="checkbox"/>	
FOR EPA USE: Samples received by _____ Date/Time: _____	
Samples transferred to Region 5 Laboratory by _____ Date/Time: _____	
EPA Use: Visible Particulate in any samples? Yes <input type="checkbox"/> No <input type="checkbox"/> If Yes – List Samples With Particulate _____	

Volunteer Certification: I have read the sampling instructions and have collected the samples in accordance with the instructions provided.

Signature/Date *OR* _____
Volunteer ID/Date

Figure S45: Sept/Oct sample collection and reporting form.

Literature Cited/References

1. Triantafyllidou, S.; Edwards, M., Galvanic corrosion after simulated small-scale partial lead service line replacements. *Journal American Water Works Association* **2011**, *103*, (9), 85-+.
2. Renner, R., Reaction to the Solution: Lead Exposure Following Partial Service Line Replacement. *Environmental health perspectives* **2010**, *118*, (5).
3. Cartier, C.; Arnold Jr, R. B.; Triantafyllidou, S.; Prévost, M.; Edwards, M., Effect of Flow Rate and Lead/Copper Pipe Sequence on Lead Release from Service Lines. *Water Research* **2012**, *46*, (13), 4142-4152.